Weeds

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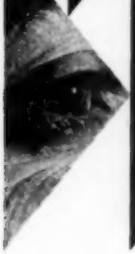

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VOLUME V JANUARY 1957 NUMBER 1

Field and Laboratory Studies on the Dormancy and Germination of the Seeds of Chess (*Bromus secalinus* L.) and Downy Bromegrass (*Bromus tectorum* L.)[1]

G. P. STEINBAUER and BUFORD H. GRIGSBY[2]

CHESS, *Bromus secalinus L.*, and downy brome, *Bromus tectorum L.*, are two of the more common and troublesome weedy grasses in the midwest and western states. Downy bromegrass is widely dispersed in Michigan in pastures, meadows, cultivated fields, and roadsides. Chess occurs frequently in grain fields, particularly in the southern part of the state. These two species have been variously described as annual (2, 3, 6, 7), winter annual (5), and either annual or winter annual (5, 1) plants.

Since reproduction of these plants is solely by seeds it seems desirable to have information on the factors conducive to seed formation and the requirements for germination of the seeds and establishment of the seedlings. Hulbert (4) has recently made an extensive study of the ecological factors in reproduction and survival of *Bromus tectorum* and other annual bromegrasses, particularly in the far western states. The results herein reported deal with the extent and dormancy of the seeds of the two species under Michigan conditions, a study of the most effective methods of determining viability in the laboratory, and observations on seed germination in the field.

MATERIALS AND METHODS

Seeds of the two species were collected in 1954 and 1955 at East Lansing, Michigan, rapidly dried and tested for viability soon after harvest, and again at a later date to check the extent of dormancy and changes in germination requirements. Germination tests were made on quadruplicate lots of 100 seeds for each treatment. All tests were carried out by placing the seeds on two thicknesses of standard germination blotters in petri dishes. Moistening agents included water and 0.2% potassium nitrate solution. Temperatures were controlled within ±1° C. Light, when desired, was supplied by a cool white fluorescent lamp in the incubator, so arranged as to yield

[1]Approved as Jour. Paper No. 1915, Mich. State Univ. Agri. Exp. Sta.

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100 to 150 foot candles illumination at the petri dishes. That the light was of satisfactory quality and intensity may be gathered from the fact that seeds of such light demanding species as *Oenothera biennis, Verbascum thapsus, V. blattaria* and *Phytolacca americana* give complete germination when exposed to this type of illumination.

Field plantings were made on September 11 and October 2, 1955 using two depths of plantings. Observations were made on the emergence of seedlings in the field as compared to germination in the laboratory.

RESULTS

Laboratory germination tests

The results of the tests are given in Tables 1 and 2. Since the seeds of the two species showed no significant improvement in germination under illumination and with nitrate solution as compared to darkness and with water as a moistening agent, the tables are simplified to include only responses to temperature variations with water as a moistening agent and without added illumination.

Table 1. Germination of seeds of *Bromus tectorum*, one week and eight weeks after harvest, in response to various temperature treatments. Data based on means of 4 × 100 seeds.

Time of test	Temperature treatment	Percentage germination	Duration of test in days
1 week after harvest	15°C constant	93	6
	20°C constant	34	9
	20°–30°C alternation[1]	2	9
	Prechill 5°C 1 week then 20°C const.	92	9
	Prechill 5°C 1 week then 20°–30°C alt.[1]	94	9
8 weeks after harvest	15°C constant	98	4
	20°C constant	98	4
	20°–30°C alternation[1]	96	4
	Prechill 5°C 1 week then 20°C constant	98	9
	Prechill 5°C 1 week then 20°–30°C alt.[1]	98	9

[1]16 hours at 20°C and 8 hours at 30°C.

Table 2. Germination of seeds of *Bromus secalinus* 1 day after harvest and 4 weeks later in response to various temperature treatments. Data based on means of 4 × 100 seeds.

Time of test	Temperature treatment	Percentage germination	Duration of test in days
1 day after harvest	15°C constant	90	9
	20°C constant	11	9
	20°–30°C alternation[1]	1	9
	Prechill 5°C 1 week then 20°–30°C alt.[1]	99	9
	Prechill 5°C 1 week then 20°–30°C alt.[1]	96	9
4 weeks after harvest	15°C constant	98	4
	20°C constant	96	4
	20°–30°C alternation[1]	96	4
	Prechill 5°C 1 week then 20°C const.	99	9
	Prechill 5°C 1 week then 20°–30°C alt.[1]	96	9

[1]16 hours at 20°C and 8 hours at 30°C.

Field germination

Seeds of chess and downy bromegrass were planted in the field on September 11 and again on October 2, 1955, at depths of 1 inch and 3 inches. Rainfall was adequate following the field plantings. Observations made on seedling emergence on November 19 indicated that over 90% of the viable seeds, as indicated by previous laboratory tests, had become well established seedlings. No significant differences were observed with respect to depth of planting.

Seed longevity

Information on the maximum duration of seed viability of these species is not available at this time. However, lots of seed collected in 1948 and stored dry in sealed containers were tested for viability in 1956. *Bromus tectorum* seeds germinated 100% and *Bromus secalinus* seeds 91%. This would indicate that under good storage conditions vitality can be maintained for many years. Little is known as to longevity in the soil. However, it seems likely that seeds at or near the surface of the soil would germinate readily whenever conditions were favorable.

DISCUSSION

Seeds of both *Bromus secalinus* and *Bromus tectorum* resemble those of many other grasses in possessing a period of primary dormancy immediately after maturity. The length of this period probably does not exceed four or five weeks in most instances. Similar behavior of seeds of these and other bromegrasses has been noted by Hulbert (4) in his studies based on plantings in Idaho, Washington, Oregon and Montana.

Seeds of both species can be readily germinated in the laboratory following maturity of the seed. During the period of primary dormancy low constant temperatures such as 15° C or higher temperatures, if preceded by a prechill treatment, will induce germination. Once the period of primary dormancy has passed the seeds will germinate well over a considerable range of temperatures. The number of days required for completion of germination falls off markedly as the period of primary dormancy passes. Suitable substrates include blotters in petri dishes, upright and horizontal rolled paper towels, folded blotters and silica sand. Water proved an effective moistening agent, although there was some indication that nitrate solution might hasten after-ripening of seeds of *B. tectorum*, when used in conjunction with a prechill treatment. Wiltse (8) found the latter moistening agent useful in testing viability of immature and freshly harvested downy brome.

Field plantings indicate that under favorable conditions all, or nearly all, of the viable seeds in contact with the soil will germinate and become established seedlings during the fall.

It is thus evident that the seedlings normally will have been exposed to a period of low temperature prior to rapid vegetative growth in the spring. On the basis of his experiments Hulbert (4) concluded that flower initiation is possible only after a low temper-

ature treatment of the moist seeds or seedlings. On this basis, the plants behave as annuals only if planted early enough in the spring so that the seeds or seedlings receive the low temperature stimulus. Otherwise they behave as winter annuals and plants from late planted seed vegetate the first season and flower during the second season. In this connection it is noteworthy that seeds of *Bromus secalinus* planted in late spring of 1955 in the Beal Botanical Garden at Michigan State University[3] produced vigorous vegetative growth but no inflorescences during the first season, suggesting that behavior of this species in Michigan resembles that observed by Hulbert in the plantings in the far western states.

SUMMARY

1. *Bromus secalinus* and *B. tectorum* seeds exhibit primary dormancy following maturity. This period extends for four or five weeks. During this period of primary dormancy low constant temperatures such as 15° C are required for germination. Higher temperatures may be used if the seeds are prechilled at 5° C for 5–7 days prior to the higher temperatures.

2. After the period of primary dormancy has passed germination occurs readily at temperatures of 20°–25° C.

3. Neither light nor alternating temperatures are requisite for germination. Water was as effective as nitrate solution as moistening agent in nearly all instances. Several suitable substrates included silica sand, paper towels, folded blotters and blotters in petri dishes.

4. Germination velocity increases with completion of the after ripening process.

5. Field plantings indicate that when conditions are favorable most of the seeds of these species probably germinate during the same season in which they are formed. These species appear to behave either as annuals or winter annuals depending upon whether or not germination occurs at a season that makes possible the exposure of the seeds or seedlings to the low temperature stimulus.

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[3]G. W. Parmelee. Personal communication. Beal Botanical Garden, Michigan State Univ., East Lansing, Michigan.

Translocation and Fate of Amino Triazole in Plants[1]

BRUCE J. ROGERS

AMINO triazole (3–amino–1,2,4–triazole) is a chemical which causes chlorosis in many plants (1). In many cases chlorosis is followed by the death of the plant. It is not known definitely whether the synthesis of chlorophyll is inhibited or whether chlorophyll is destroyed. Generally, only new growth, in which the pigment is being formed, shows chlorosis. This suggests that chlorophyll synthesis is affected. The chlorosis has been shown to be proportional to the amount of amino triazole applied (2). In order to establish a basis for further work, evidence on the translocation and fate of the chemical in several different plants is presented here.

MATERIALS AND METHODS

Amino triazole[2] (AT) labeled in the number 5 position with carbon–14 (specific activity 1.27 mc/mmole) was used in these studies. Potted soybean and Canada thistle plants, and Johnsongrass shoots grown in the laboratory from rhizomes, were each treated with 2 mgs. (approximately 30 uc/plant) of the radioactive material. The AT was applied in a drop of water to the axil of the first trifoliolate leaf of the soybean plants, to the base of the blade of the lower leaf of the Johnsongrass shoots, and to a leaf axil about two inches below the apical leaf of the Canada thistle plants. During the experiment the plants were maintained, well irrigated, under a bank of fluorescent lights at a temperature of 75° F. Approximately 70 hours after treatment with the radioactive AT the plants were harvested.

Radioautography. The plants were washed free of soil and dried in a plant press overnight at 90° F. The soybean plants were laid flat. The Johnsongrass shoots were laid flat, the rhizomes cross-sectioned laterally and the thin sections, with roots detached, were easily handled. The Canada thistle plants were treated somewhat differently. In order to dry them flat with each leaf fully visible, the leaves were detached from the stem and arranged around the stem in the same position, relative to each other, that they had occupied on the intact plant. The rhizomes were split longitudinally and dried flat.

When dry, the plants were fastened to thin sheets of cardboard (14×17 in.) with a fast-drying cement applied at as few points as needed to hold them in position. Then, in a darkroom, 14×17-inch sheets of No-Screen x-ray film were laid directly on top of the plants, and the cardboard, plus film, put into lead-lined folders. Large sheets of lead were placed on top of the folders to assure close contact of the film with the plants. After 10 days, the film was removed and developed by appropriate means.

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[1]Contribution from the Dept. of Botany and Plant Pathology, Purdue University, Lafayette, Indiana. Journal Paper No. 975, Purdue University Agri. Exp. Sta.

[2]Provided by the American Chemical Paint Co., Ambler, Penna.

Chromatography. The aerial portions of the dried plants, after radioautography, were ground to a powder and extracted with 100 ml of acetone and then 100 ml of water. The water extract was boiled for 10 minutes to precipitate protein, which was then separated from the solution by centrifugation. The acetone and water extracts were evaporated almost to dryness and aliquots of each were then applied in the form of small spots to a paper chromatogram (Whatman #1, 11×11 in.). Approximately equal volumes of each extract were applied. A reference spot of pure C^{14}-AT was also applied in water and the chromatograms developed with liquefied phenol (Mallinckrodt "Gilt Label") by an ascending technique for 12 hours. After the run, a strip of paper which included the entire path of each spot was cut from the chromatogram and divided into ½-inch segments, numbered consecutively from the point of origin to the solvent front. The radioactivity of each segment was determined by means of a thin-window G-M tube and scaler. The data were plotted with the numbered segments in order on the abscissa and the radioactivity in counts per minute on the ordinate.

RESULTS

Radioautographs of soybean and Canada thistle plants are shown in Figures 1, 2, and 3. The darkened areas denote the presence of radioactivity. The film was exposed a little too long for the dosage used—the dosage was deliberately large in order to carry out the chromatographic investigations. The labeled carbon was trans-

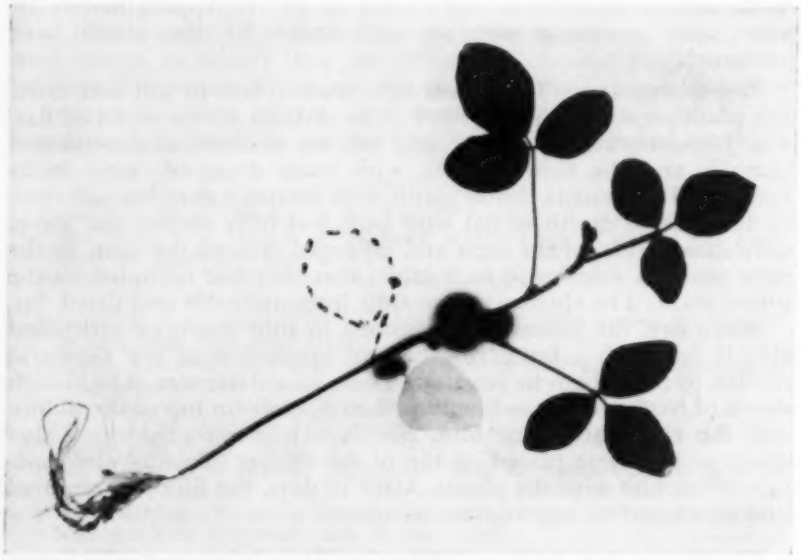

Figure 1. Radioautograph of a soybean plant treated with C^{14}–AT. Dashed line indicates position of a primary leaf.

located throughout each of the plants in the 70-hour period. In another experiment a similar widespread distribution was noted in plants in which translocation was allowed to proceed for 30 hours after application of C^{14}-AT (4). Although it is impossible to see in Figure 1, the AT or some radioactive metabolite entered even the hairs on the soybean stems. The radioactive compound passed from the stems to the roots in the three plants. It also traveled some six inches through the rhizome from a treated (Figure 2) to an untreated Canada thistle plant (Figure 3). Many of the small black spots on the leaves and stem of the thistle plant in Figure 3 were found to coincide with the dead bodies and debris of aphids—evidently these sucking insects had concentrated C^{14}-AT or a metabolite from the vascular tissues.

Figure 2. Radioautograph of a Canada thistle plant treated with C^{14}-AT.

In Figures 4, 5, and 6, are shown the chromatographic data for the water and acetone extracts prepared from the three plants. The slight differences in the position of the AT peak from figure to figure are due to differences in height of the solvent front for the three chromatograms. The fourth curve in Figure 4 (marked "water and AT") represents an additional experiment carried out to test

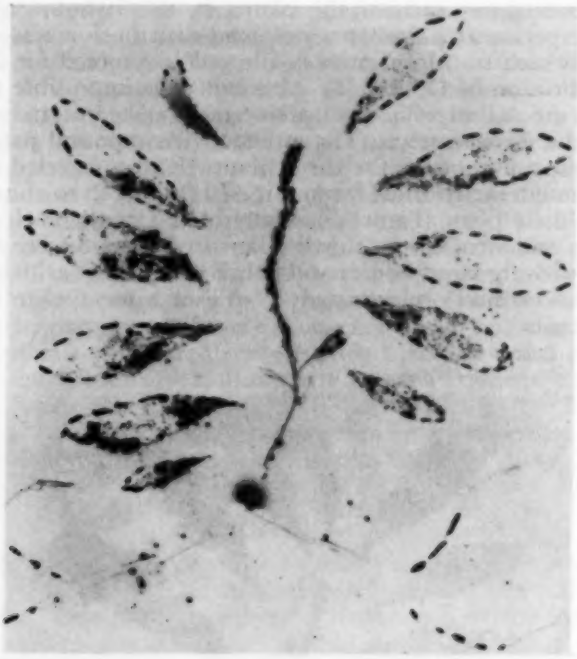

Figure 3. Radioautograph of a Canada thistle plant which was connected by a rhizome, visible at the base of the plant, to the treated plant shown in Figure 2. Dashed lines indicate the position of leaves and roots.

the possibility that the peaks might be artifacts caused by the preparative process. Non-radioactive soybean leaves were extracted with water and then a small amount of C^{14}-AT was added. The subsequent procedure as given above was followed. The treatment of the non-radioactive tissue was such that most enzymes would be denatured. Thus, any changes in the AT molecule might be presumed to be non-enzymatic in origin.

DISCUSSION

It may be adduced from field observations that AT (or some effective metabolite) tends to accumulate in the younger leaves of Canada thistle plants, and is translocated from one thistle plant to another. This is now confirmed by radioautographic evidence. Field tests in Indiana have shown that soybean and Canada thistle plants will tolerate little AT—about 4 lbs/A or less (3). Johnsongrass at a comparable stage of growth appears to be more resistant (5). It is apparent that this resistance is not brought about by lack of translocation. Another explanation must be sought. It may be that a

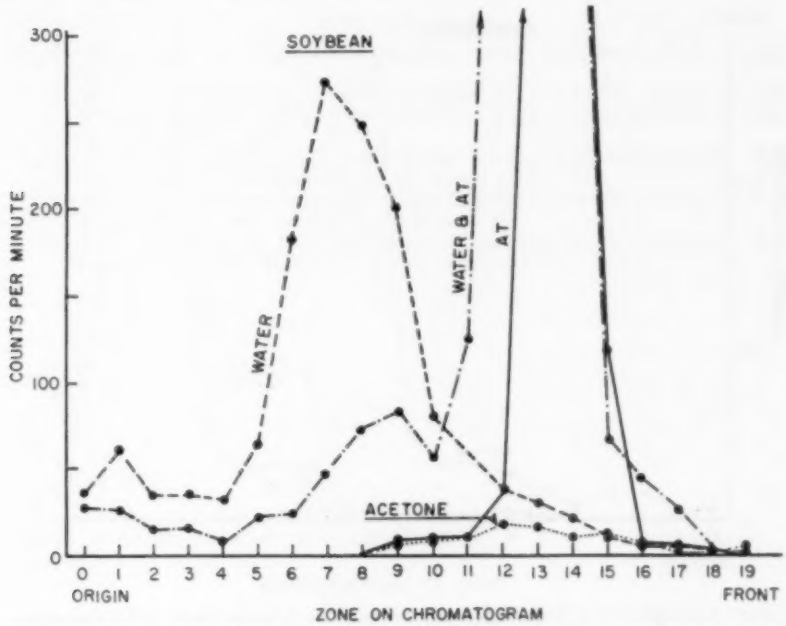

Figure 4. Graph of the distribution of radioactivity as taken from a chromatogram of acetone and water extracts of a soybean plant treated with C^{14}-AT.

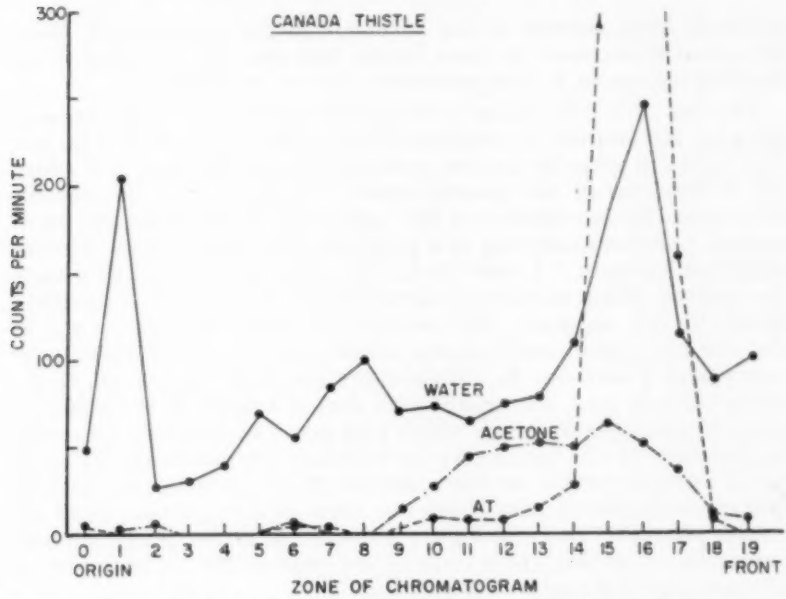

Figure 5. Graph of the distribution of radioactivity as taken from a chromatogram of acetone and water extracts of a Canada thistle plant treated with C^{14}-AT.

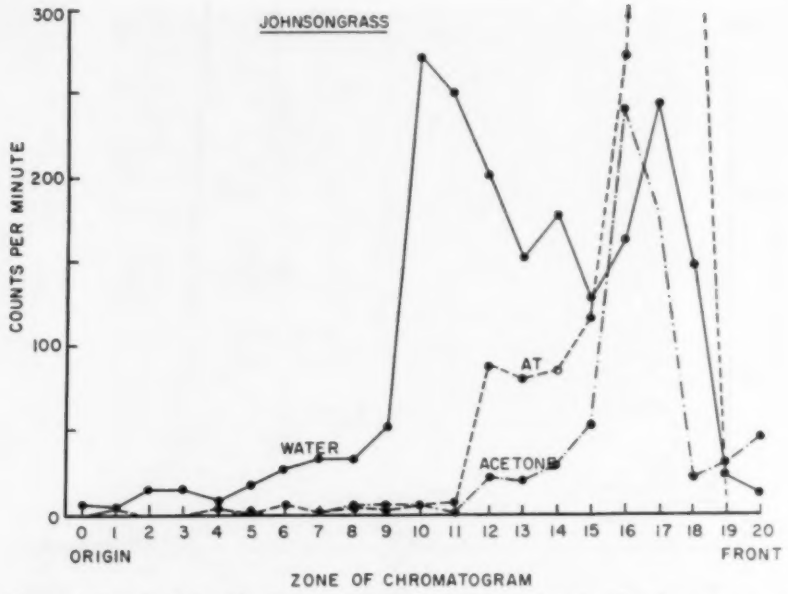

Figure 6. Graph of the distribution of radioactivity as taken from a chromatogram of acetone and water extracts of a Johnsongrass plant treated with C^{14}-AT.

relatively large amount of the herbicide in the meristematic tissue of a plant is necessary to cause death, and that the position of the growing regions in grasses precludes such an accumulation.

The fate of AT in plants is being studied by tracer and chromatographic techniques, as illustrated in Figures 4, 5, and 6. The acetone peaks in these figures are probably caused by pure AT which was washed out of the ground plant material during the acetone extraction. The variability of the radioactive peaks from the water extracts presents something of a problem. The peaks which coincide with that for pure AT most probably represent AT. On this basis, the soybean plant apparently metabolized, in one way or another, all of the AT supplied. The radioactive peaks near the origin in the case of soybean and Canada thistle represent some radioactive entity with a very low R_f value—there was little movement in the solvent system used. This early peak does not occur in the Johnsongrass chromatogram—a fact which may prove to be pertinent to any explanation of the variability in tolerance of plants to AT. The peaks which appeared in the center of the chromatograms may be due to enzymatic activity; however, there is a suggestion from the "water plus AT" curve in Figure 5 that these center peaks are non-enzymatic in origin. The nature of the radioactive peaks found for all three plants is under investigation.

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Germination and Growth Inhibitors in Leafy Spurge Foliage and Quackgrass Rhizomes[1]

DUANE LE TOURNEAU[2] and H. G. HEGGENESS[3]

NUMEROUS workers have reported the presence of growth and germination inhibitors in various plants (1, 2, 3, 4, 5, 7). In some cases the active principles have been isolated and characterized. It has been further found that some of these inhibitors have a role in the interaction of species. Thus, the compound, 3 acetyl–6–methoxybenzaldehyde, is leached from the leaves of *Encelia farinosa* and suppresses the establishment of other species in the immediate vicinity of the parent plant (2).

A study was begun to determine the possible occurrence of inhibitors in common weed and crop species. All of the species tested were found to contain heat stable water-soluble materials affecting the germination and/or growth of germinating wheat or pea seeds (7).

Further studies were made to isolate and characterize inhibitors in leafy spurge *(Euphorbia esula)* and quackgrass *(Agropyron repens)* rhizomes. A portion of this work has been previously summarized in abstract form (5).

MATERIALS AND METHODS

Leafy spurge plants, collected from various sites at St. Paul, were dried in a forced air drier at 55–60° C for 24–48 hours and ground to pass a 40-mesh screen in a Wiley mill. Extracts of fresh material were obtained from leafy spurge plants grown in the greenhouse.

Quackgrass rhizomes (from actively growing plants) were placed in a forced air drier, freed from adhering soil particles, and ground to pass a 40-mesh screen.

Unless otherwise noted, extracts were made by weighing a quantity of dry plant material and adding to it 100 ml of distilled water. This mixture was then extracted with constant stirring for 20 minutes according to the method of Helgeson and Konzak (4). The extracts were then clarified by filtration on a Buchner funnel. Concentrations are expressed as 1/100, 2/100, etc., indicating the amount of material extracted with 100 ml of water.

Responses of both germinating peas and wheat were used to assay inhibitor activity in the plant samples. However, the pea assay was preferred as it was more reproducible and not as subject to microbial contamination. Briefly, the pea assay (7) consists of placing 10 surface sterilized (2 per cent sodium hypochlorite for 10 minutes) Alaska peas in a sterile petri dish containing blotter paper and 10 ml of

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test solution. The plates were then placed in a Mangelsdorf germinator at 21–25° C. for 5 days. At the end of this period the root length of the germinated seeds was measured to the nearest mm. Assays were made in triplicate and each extract tested at two different dates.

RESULTS AND DISCUSSION

Leafy Spurge Foliage. Aqueous extracts of leafy spurge foliage inhibited wheat root growth when the ratio of spurge extracted with water exceeded approximately 0.4/100. Increasing the amount of spurge extracted increased the inhibitory effect until coleoptile growth and germination were also adversely affected (7). Leaf extracts were more inhibitory than stem extracts (7).

Figure 1 illustrates the effect of spurge extracts on germinating Alaska peas. Germination and shoot growth were not noticeably affected. However, the roots were much shortened, the root hair zone was discolored and quite often short stubby secondary roots developed above this discolored zone after 2 to 4 days.

Experiments were made to determine if extracts of freshly harvested material were also inhibitory. The plants were autoclaved 5 minutes at 5 pounds pressure and chopped in a Waring Blendor. The mixture was then filtered and autoclaved, and the filtrate was

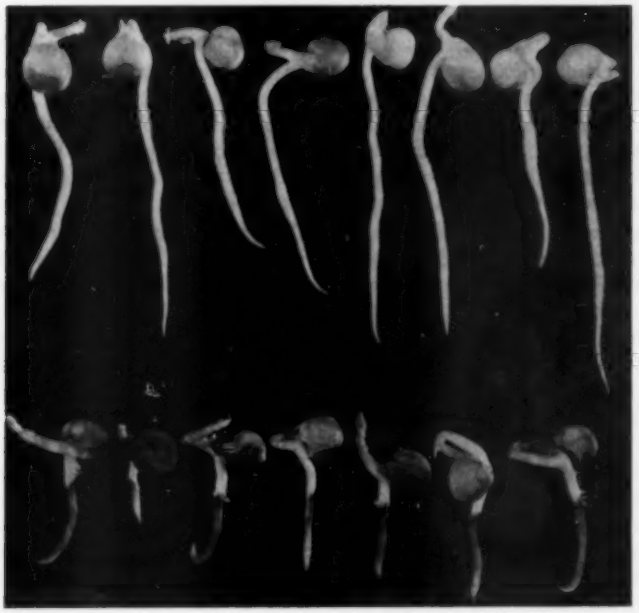

Figure 1. The effect of aqueous extracts of leafy spurge on germinating Alaska peas. Upper: distilled water controls. Lower: germinated in presence of 10 ml. of cold water extract (5 gms. extracted with 100 ml. H_2O). Note the shortening, the discoloration in the root hair zone and the secondary roots developing above the discolored area.

tested on germinating wheat and peas. Calculated on a dry basis, these extracts were somewhat more inhibitory than extracts of dried ground material.

Experiments to determine the properties of the inhibitory compound (or compounds) were made with the dried material or with aqueous extracts of the dried material. Generally, each test was carried out with a small quantity, 50 to 100 ml, of aqueous extract.

Various experiments were made to determine the solubility of the inhibitor. It was found that one aqueous extract did not remove all activity. When 5 grams of the spurge were extracted three consecutive times with 100 ml of water, the first, second and third extract inhibited pea root growth 48, 34 and 15 per cent, respectively. The addition of equal volumes of acetone or ethanol to aqueous extracts resulted in a dark flocculent precipitate. Subsequent tests of the precipitate and the supernatant (solvent removed by distillation under reduced pressure) showed the inhibitor to be in the supernatant. Extracting the ground material with benzene in a Soxhlet extractor did not remove the active fraction. On the other hand, Soxhlet extraction with methanol or 80 per cent ethanol removed the inhibitor. The complete extraction with ethanol, as judged by the assay, was not completed unless extraction periods of 12–15 hours were employed.

Attempts were made to extract the inhibitor from aqueous solution with organic solvents. Three extractions with equal volumes of ethyl ether in a separatory funnel did not remove the inhibitor when the aqueous solution was adjusted to pH 2, 7 or 10. Similarly, three extractions with equal volumes of chloroform did not remove inhibitory activity from an aqueous solution of pH 11. Preliminary experiments indicated that some activity was removed from an aqueous solution by extracting wth n-butanol.

Other experiments showed that the inhibitory fraction is dialyzable and stable to autoclaving at pH 2 or 11 for 1 hour at 15 pounds pressure. Repeated experiments showed that activity was not lost from solution when distilled under the reduced pressure of a water aspirator. Similarly, the inhibitor was retained when the extract was made alkaline (pH 10 to 11) and then distilled. No inhibition resulted from adding the ash of 0.5 or 1.0 gm of ground spurge to the petri dishes. The ash represented 9 per cent of the original sample.

The inhibitor was not removed from aqueous solution by Lloyd's alkaloid reagent. However, treatment with Norit (activated carbon) removed much, but not all, of the inhibitor from solution. One and 5 gm of Norit were each added to 100 ml of the extract and stirred continuously for 20 minutes. At the end of this time the carbon was filtered off and the filtrates tested. Root growth as compared to control was inhibited 30 per cent and 15 per cent, as compared to 50 per cent for the original spurge extract. Ten gms of Norit per 100 ml of extract did not remove all inhibitory activity from the original extract. The Norit treatment eliminated discoloration in the root hair zone and retarded secondary root formation.

Norit treatment removed the yellow coloring materials from the

extracts to yield essentially clear solutions. This suggested that some of the anthoxanthins or similar materials were responsible for inhibition. Assays with rutin, quercitrin, quercetin, and similar materials have shown these materials are not inhibitory. Further, extracts of the ground plant tissue made with 0.01 *N* HCl were essentially colorless yet they were inhibitory.

A limited number of experiments were made to determine if the inhibition could be removed from aqueous solution with ion exchange resins. An anion exchange resin in the hydroxyl cycle (1RA–400) did not remove activity. Cation exchange resins in the hydrogen cycle (1RC–50 and 1R–100) and a monobed resin (MB–3) all removed some, but not all, activity from aqueous solutions. The monobed resin removed approximately 60 per cent of the total solids. An active preparation was obtained from the cation exchange resin 1RC–50 by eluting with 0.01 or 0.1 *N* HCl. These experiments were made using batch extractions. Further experiments using column techniques and other resins under a wider range of conditions are desirable.

If wheat seedlings inhibited by the spurge extracts were removed from the extracts and washed with distilled water, they resumed growth in control dishes. It was noted, particularly in the wheat assay, that the pH of the spurge extracts became alkaline during the germination period. The addition of KH_2PO_4 to the extracts in amounts sufficient to overcome this pH change did not alter the effect of the extracts.

No adverse effects on plant growth were observed when the extracts were sprayed on wheat, bean or tomato foliage. Similarly, the incorporation of 10 or 20 gms of the ground material per 6-inch pot of soil did not affect the plants. The lack of activity in the soil may be due to the inhibitor being adsorbed by the soil or to microbiological breakdown. Using the pea assay, it was found that treating aqueous extracts with autoclaved soil (as with Norit) removes some activity. Other experiments showed that various soil microorganisms grew well in liquid or agar media made from the extracts. Of the various species tested, only *Pythium butleri* appeared to be inhibited by the extracts.

From the characterization experiments certain classes of compounds may be eliminated as the cause of inhibition. The solubility in alcohol, 50 per cent acetone and dialyzability eliminates large molecules such as protein, pectin or polysaccharides. Alkaloids have often been shown to be growth and germination inhibitors (3). The material in spurge is not adsorbed by Lloyd's alkaloid reagent. Further, extraction of the basic aqueous extract with chloroform, a technique effective in extracting most alkaloids (8), did not extract any of the activity. Ammonia also is a common inhibitor (3), but the spurge inhibitor was not distilled from basic solution. Some aromatic acids and neutral compounds would be removed by ether extraction from acidic or neutral aqueous solution. Negatively charged materials could be expected to be removed by the anion exchange resin.

Certain observations indicate that there may be two inhibitors or fractions. Thus, adsorption by charcoal, extraction with n-butanol, and treatment with cation and monobed resins have all removed some, but not all, activity. Preliminary tests of the weak acid eluate of the cation exchange resin indicated the presence of nitrogen in this fraction. Part of the activity may thus be a basic nitrogen compound. One unknown compound reacting with ninhydrin has been found in the ethanol soluble fraction (6).

The further isolation procedures to be employed are limited by the bioassay. As an example, if the material contained basic nitrogen, it might be precipitated by phosphotungstic acid. Preliminary control experiments to remove excess phosphotungstic acid with barium carbonate have shown that either enough acid or barium remained to inhibit the assay. Similarly, procedures that add excess salts may also affect the assay. In this connection, it is to be noted that the pea assay is less sensitive to osmotic pressure than the wheat assay (7). It is suggested that procedures combining butanol extraction and resin treatments might profitably be used.

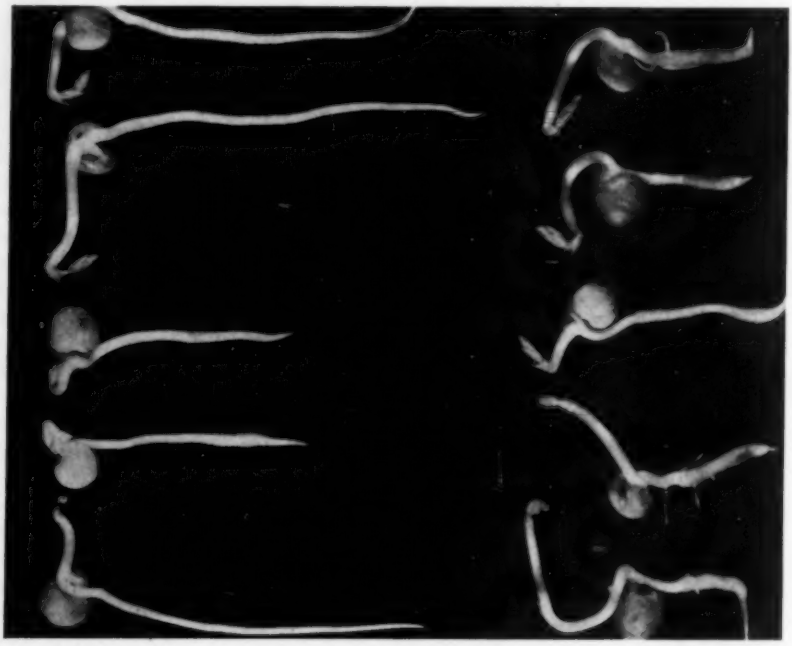

Figure 2. The effect of aqueous extracts of quackgrass rhizomes on growth of Alaska pea seedlings. Left: distilled water controls. Right: germinating peas treated with 10 milliliters of rhizome extract (5 gms. extracted with 100 ml.). Note the shortened, thickened appearance, the discoloration and the secondary roots of the treated seedlings.

Quackgrass Rhizomes. Experiments made with aqueous extracts of ground rhizome material showed that inhibition of peas and wheat occurred when amounts greater than approximately 0.10 gm were extracted with 100 ml of H_2O. The effect of rhizome extracts is shown in Figure 2. Data concerning the effect of these extracts on peas and wheat are given in Table 1. With wheat the first effect was an inhibition of root growth. This was followed by reduction of coleoptile growth and as the concentration was increased still further, germination is affected. With peas the only noticeable effect was an inhibition of root growth. Often this was accompanied by thickening of the root and slight discoloration in the root hair zone.

Attempts to characterize the quackgrass rhizome inhibitor (or inhibitors) were not as extensive as those with spurge. As with spurge, it was found that considerable activity remained after one aqueous extraction. Extraction with methyl alcohol in a Soxhlet extractor removed almost all of the inhibitor from the ground plant material. Acetone extraction also removed some activity but it was not as efficient as methanol extraction. Benzene or diethyl ether did not extract the inhibitor. The inhibitor was dialyzable and was not lost by concentrating by vacuum distillation (aspirator). The ash did not have inhibitory activity.

Table 1. The effect of various concentrations of cold aqueous extracts of quackgrass rhizomes or germinating peas and wheat. Concentration of extract refers to grams of rhizomes extracted with 100 ml. of H_2O.

Concentration of extract	pH	Pea root length (cm.)	Per cent root inhibition	Range wheat root length (cm.)	Range wheat coleoptile length (cm.)	Per cent wheat germination
0	—	5.2	—	6–8	3–5	85
1/100	6.7	2.8	46	2–3	2–4	84
2.5/100	6.4	2.5	52	1–2	2–4	78
5/100	6.3	2.4	54	1–2	2–4	70
10/100	6.2	2.0	61	1	1–3	72

When treated with Norit, the aqueous solution became colorless. Assay of the filtrates from Norit-treated material showed that inhibition was greatly reduced (see Figure 3). Not all of the inhibitory action was removed with Norit. By adding increasing amounts of Norit to aqueous extracts, a maximum concentration was reached and further additions were no longer effective in removing activity.

Efforts to remove the inhibitor from aqueous solution with a cation exchange resin (IRC–50) in the hydrogen cycle and an anion exchange resin (IR–4–B) in the hydroxyl cycle were not successful. Further experiments with other resins are desirable. If the inhibitor is neutral, it should be possible to greatly purify it by removal of contaminating anions and cations with these resins.

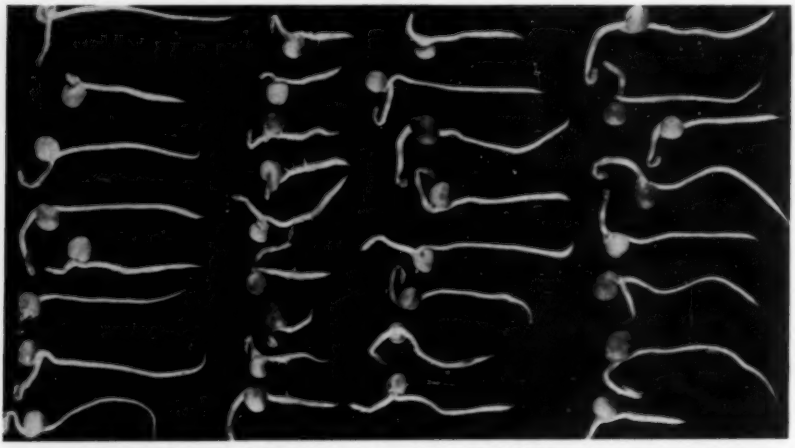

Figure 3. The effect of Norit treatment on the inhibition of quackgrass rhizome extracts on pea root growth. From left to right, respectively: controls, original rhizome extract, original rhizome extract treated with 1 gm. Norit per 100 ml. of extract, and original rhizome treated with 5 gms. of Norit per 100 ml. extract.

SUMMARY

Aqueous extracts of fresh or dried leafy spurge foliage inhibited root growth of pea and wheat seedlings. Increased concentrations inhibited coleoptile growth and the germination of wheat. The inhibitor (or inhibitors) was dialyzable, non-volatile, and soluble in water, methanol, 50 per cent acetone and 80 per cent ethanol. The inhibitor was insoluble in benzene and ether extraction did not remove activity from acidic, neutral or basic aqueous solution. Chloroform did not extract activity from basic solution. The ash of the dried foliage was not inhibitory. Lloyd's alkaloid reagent and an anion exchange resin did not remove activity from aqueous solution. A portion of the inhibitory activity was removed from solution by Norit, cation exchange resins, and butanol extraction. It is suggested that there may be at least two active fractions.

Aqueous extracts of quackgrass rhizomes inhibited root growth of pea and wheat seedlings. Increasing the amount of rhizome material increased the inhibition. Higher concentrations inhibited wheat coleoptile growth and germination of wheat seed. The inhibitor (or inhibitors) was soluble in methanol and 80 per cent ethanol but not in benzene or ether. It was dialyzable and non-volatile. An anion and a cation exchange resin did not remove activity from solution. Treatment of the aqueous solution with Norit removed most of the inhibitor from solution.

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The Effects of Fresh Water Storage on the Germination of Certain Weed Seeds. II. White Top, Russian Knapweed, Canada Thistle, Morning Glory, and Poverty Weed[1]

V. F. Bruns and L. W. Rasmussen[2]

In 1949, Bruns and Rasmussen (1) initiated studies to determine the length of time certain weed seeds would maintain viability when held in fresh running water. Seeds of white top, Russian knapweed, Canada thistle, morning glory, and poverty weed were placed in Lumite screen bags and submersed at 12- and 48-inch depths in the Prosser Power Canal.

Periodic germination studies indicated that 98 percent or more of the white top seeds were no longer viable after six months of water storage. However, a relatively high percentage of the seeds of Canada thistle, Russian knapweed, morning glory, and poverty weed remained sound and germinated after 22 months. Also, an inverse relationship was noted between the germination of these seeds and the temperature of the water in the canal at the time of removal for germination studies. These results prompted the initiation of a second test to determine the viability of the same species over a period extended to five years.

Methods and Materials

The same methods and materials as previously described (1) were used with only slight modification. Seeds of white top (*Cardaria draba* (L.) Desv. var. *repens* (Schrenk) O. E. Shulz), Russian knapweed (*Centaurea repens* L.), Canada thistle (*Cirsium arvense* L.), morning glory (*Convolvulus arvensis* L.), and poverty weed (*Iva axillaris* Pursh.) were collected. Seven thousand two hundred seeds of each species were divided into sample lots of 100 seeds. These lots were placed in separate Lumite screen bags (36-mesh) which were sewed with nylon thread. Five bags, each containing 100 seeds of a different weed species, were grouped to form composite samples for later germination studies. Holes were drilled approximately three inches apart in pipe standards to which the composite samples were fastened individually by means of grass bolts and nuts on July 22, 1950.

The standards were constructed from ½-inch galvanized iron pipe in the form of an inverted T-on-T. Thus, the seeds could be held at both 12- and 48-inch depths in the water. Each pair of arms of a standard initially supported 12 composite samples. Three separate standards, placed 20 feet apart, were used as replicates.

Each standard was attached to the hand-rail of the catwalk at the fish screens in the Chandler Power Canal, Prosser, Washington. The

[1]Studies conducted at the Irri. Exp. Sta., Prosser, Washington. Published jointly by the U. S. Dept. of Agric. and the Washington Agric. Exp. Sta. Scientific Paper No. 1505, Washington Agri. Exp. Sta., Pullman. Project No. 951.

[2]Agronomist, Field Crops Research Branch, ARS, USDA, and Agronomist, Washington State College, respectively.

attachments were designed to permit convenient raising and lowering of the standards for depth adjustments as well as for removal of samples for germination studies.

Composite samples from both the 12- and 48-inch depths were removed from each standard for germination studies at 2, 4, 8, and 12 months and every 6 months thereafter over a period of five years. Upon removal, the number of seeds germinated and/or disintegrated was determined. The seeds which appeared sound were placed in a germinator (68° to 72° F.) and observed over a period of four weeks. In addition, comparative germination studies were made on dry-stored seeds of the same species and source. The seeds were not scarified.

Temperature of the water in the canal was recorded at frequent intervals during the storage period.

RESULTS AND DISCUSSION

Germination of Dry-stored Seeds. The germination trends of the seed held in dry storage are shown in Figure 1. The germination of white top seed declined somewhat gradually from an initial 66 percent to 17 percent at the end of the 5-year period. The germination of Russian knapweed seed fluctuated considerably between a low of 31 and a high of 81 percent during the same period. Oddly, no germination of poverty weed seed was obtained. After 12 months, the supply of dry-stored seeds of Canada thistle and morning glory was exhausted. However, during this first-year period, the germination of Canada thistle seed ranged between 23 and 63 percent while that of morning glory seed ranged from 5 to 17 percent.

Disintegration of Submersed Seeds. Some of the weed seeds germinated and/or disintegrated while submersed in fresh water. When

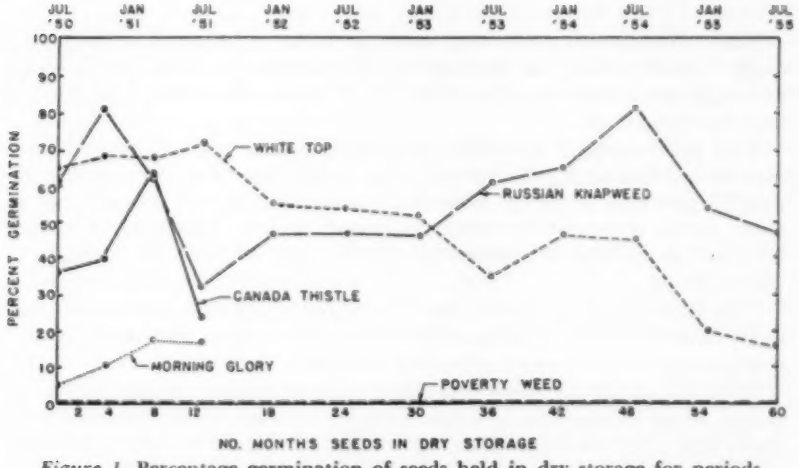

Figure 1. Percentage germination of seeds held in dry storage for periods ranging from 0 to 60 months.

the seed packets were removed from the water, the apparently normal, whole seeds present were counted. The difference between the number of seeds placed in the packets at the beginning of the test and those present at removal time represented the loss shown as percentage non-viable seed in Figure 2. Because no consistent and significant differences in either percentage disintegration or percentage total germination of seeds held at different depths in the water were obtained, the data presented graphically in Figures 2 and 3 represent the means from both the 12- and 48-inch depths of storage.

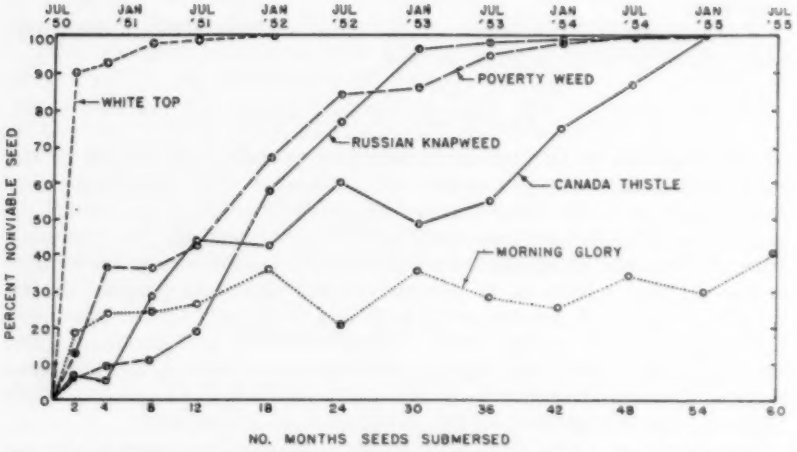

Figure 2. Average percentage of seeds which had germinated and/or disintegrated during submergence in fresh water at 12- and 48-inch depths for periods ranging from 0 to 60 months.

The viability of white top seeds in water storage was destroyed quite rapidly, with an average of 91 percent of these seeds being unsound after two months. After 19 months, all seeds of white top had disintegrated.

The percentage of germinated and/or disintegrated seeds of Russian knapweed and poverty weed increased most rapidly during the first 30 months. After 30 months, averages of 96 and 86 percent of these seeds, respectively, were no longer sound. However, all seeds had not definitely disintegrated until after 54 and 60 months of water storage.

The percentage of unsound seeds of Canada thistle increased gradually over a period of 54 months. After this length of time in water storage, the soundness of all seeds had been destroyed.

Seeds of morning glory appeared most resistant to the action of water. After 19 months of water storage, a mean of 36 percent of the seeds had germinated and/or disintegrated. However, after a period of five years in the water, only 41 percent of the seeds appeared unsound.

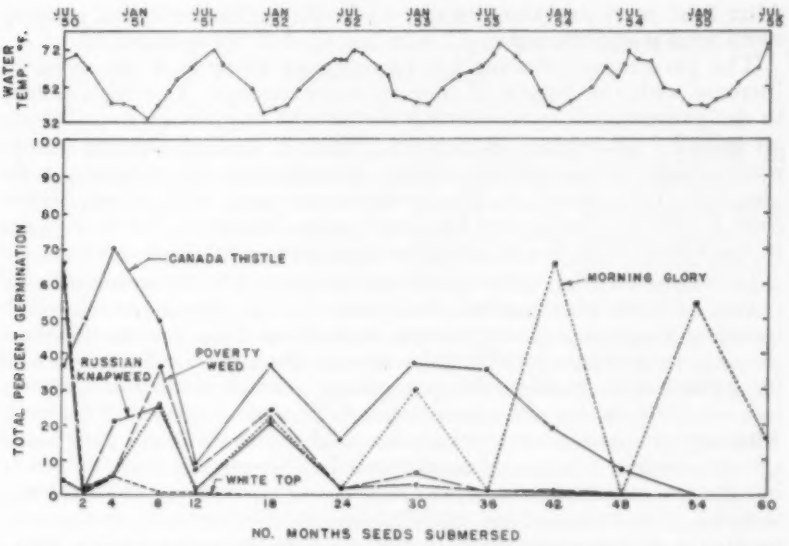

Figure 3. Temperature of the water and the average total percentage of seeds which germinated after submergence at 12- and 48-inch depths for periods ranging from 0 to 60 months.

Germination of Seeds After Submergence. When the composite samples were removed from the canal at the various intervals for germination studies, only the seeds which appeared sound were placed in the germinator. However, the total percentage germination, as presented graphically in Figure 3, was based on the initial number of seeds per sample and the number of seeds sprouting in the germinator.

Total germination of white top seed dropped sharply from 66 percent to an average of 2 percent after two months of storage in the canal. With 5 percent germinating after four months, less than 1 percent germinated after 8 and 12 months of water storage. None germinated after 19 months.

The total germination of Canada thistle increased from 36 to 70 percent after four months in the water. Thereafter, the percentage germination fluctuated between 50 and 7 until no seeds sprouted after 54 months.

Similar to white top, the percentage germination of Russian knapweed seed decreased sharply from 62 to 2 after two months in water storage. However, germination thereafter fluctuated between 25 and 1 percent during the next 46 months. No germination was obtained after 54 months.

No germination of poverty weed seed was obtained from samples held in the water for two months. The dormancy of a few seeds was broken after four months of storage. The highest percentage germination (36 percent) was obtained after eight months. Germination fluctuated between 24 and 1 percent during the next 34 months.

After four years in water storage, no further germination of poverty weed seed was obtained.

The percentage germination of morning glory seed appeared to increase with the length of time in water storage. The high points in the germination curve during the first 30 months increased from an initial 5 percent to 30 percent. After 42 and 54 months in the water, highs of 65 and 55 percent germination, respectively, were obtained. Low points in the germination curve ranged no higher than 2 percent during the first four years. However, the low point in the curve after five years of water storage was 16 percent.

Germination-Water Temperature Relationship. As previously reported (1), the germination of Canada thistle, Russian knapweed, morning glory, and poverty weed seeds showed an inverse relationship to the temperature of the water in the canal. When removed for germination studies, the percentage germination obtained was low when the water temperature was high and vice versa (Figure 3). Although the percentage germination of the seeds of all four weed species exhibited a pronounced trend in this respect, that of morning glory was perhaps the most marked and extreme example. When samples were removed for germination studies in July, water temperatures and temperatures in the germinator were similar (68°–72° F.). When removed in January and placed in the germinator, the seeds were subjected to the greatest change in temperatures (34–41° F. to 68–72° F.). This rapid change or alternation of temperatures may have influenced appreciably the germination of these weed seeds.

SUMMARY

Samples of seeds of five different weeds were submersed at 12- and 48-inch depths in a canal and removed at various intervals over a 5-year period for germination studies.

Storage in fresh water increased the percentage germination of morning glory seed (*Convolvulus arvensis* L.) over the 5-year period but no seeds of Canada thistle (*Cirsium arvense* L.) or Russian knapweed (*Centaurea repens* L.) germinated after 54 months and no viable seeds of poverty weed (*Iva axillaris* Pursh.) remained after 48 months. The viability of white top seed (*Cardaria draba* (L.) Desv. var. *repens* (Schrenk) O. E. Shulz) was destroyed rapidly with 95 percent or more failing to germinate after two months and all seeds being disintegrated after 19 months.

The germination of all seeds except white top fluctuated considerably during the course of the experiment and substantiated an earlier discovery of a pronounced inverse relationship between germination and temperature of the water in the canal.

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Influence of 2,4–D on the Uptake of Minerals from the Soil[1]

ANSON R. COOKE[2]

THE application of 2,4–dichlorophenoxyacetic acid (2,4–D) in herbicidal concentrations to plants has resulted in a number of correlations with post-treatment physiological and biochemical changes. Whether these changes are of a secondary nature or actually involved in the basic mechanism of herbicidal action cannot always be determined at the present time. One such case is the influence of 2,4–D on the uptake of minerals from the soil. Wolf et al. (7) demonstrated that the content of potassium was considerably lower and calcium was higher in leaves of 2,4–D treated plants than in controls, but when the analyses from the leaves were combined with those of the stems, these differences largely disappeared. They also noted that chlorine and sulfur were higher in treated plants than in controls, while phosphorus was lower in treated plants than in controls. Fang and Butts (1) showed that the amount of phosphorus in the leaves from 2,4–D treated plants was much less than that found in the leaves of control plants, while the amount in either the stem or root from these two groups of plants showed no significant differences. These results have been confirmed by Rebstock et al. (3) who have shown that the total amount of phosphorus in treated plants was lower than that in the control plants, while at the same time the total phosphorus content of the stem tissue from 2,4–D treated plants was higher than that of the non-treated plants. The phosphorus content of the roots was not appreciably changed from that of the non-treated plants. Rhodes et al. (5) noted that treatment with 2–methyl–4–chlorophenoxyacetic acid (MCPA) greatly lowered the potassium content of tomato and rape plants and suggested that the possible mechanism of MCPA action might be by interference with potassium metabolism. However, in a later publication Rhodes (4) reported no effect of MCPA on the uptake of potassium, calcium or magnesium. With the possibility existing that 2,4–D exerts its action through interference with potassium or phosphorus metabolism, the present study was undertaken to examine more closely the influence of 2,4–D on mineral uptake from the soil.

MATERIALS AND METHODS

Bean plants, var. Top Crop, were grown in 4 inch clay pots containing fertile soil until the primary leaves were fully expanded. At the start of each experiment the plants were divided into two groups. One group served as controls while the other group was treated with 2,4–D. The treated plants were sprayed to run-off with a solution containing 2,4–D acid and Dreft or Joy as a wetting

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agent. The concentration of 2,4–D used was 100 mg/l. This is a non-herbicidal concentration for the variety of bean plant used. Little effect on the treated plants could be noted after 24 or 48 hours except for a bending of the epicotyl region of the stem. A radioactive isotope of the mineral ion under study was dissolved in water, and aliquots of this solution were added to the soil of both the treated and untreated plants. The plants were then watered to insure an even distribution of the isotope throughout the soil. At intervals after the addition of the isotope to the soil, the activity of the isotope throughout the plant was determined. Identical samples were taken from both the treated and control plants and in the majority of determinations duplicate plants of each were sampled. Samples were taken from each of the two primary leaf blades and petioles, from the shoot tip, and from the epicotyl and hypocotyl regions of the stem. These sampled tissues were weighed so that the activity in the control and treated samples could be compared on a fresh weight basis, and then placed on nickel planchets and counted with a thin end-window Geiger counter. The activity recorded was corrected for background but not for natural decay of the isotope, as the treated and control samples were always counted within a few minutes of each other. The results of each experiment were expressed as a percentage of the activity recorded in the control plants.

EXPERIMENTAL RESULTS

Potassium

A group of 16 bean plants with fully expanded primary leaves were divided into two groups. One group was then sprayed to run-off with a solution containing 100 mg./l of 2,4–D and 0.5% Joy. Five hours later, 355 microcuries of K^{42} in the form of $K^{42}CO_3$ in 50 ml of water were added to the soil of each pot of the treated and control plants. Samples were taken of the various plant tissues at several intervals during the next 24 hours, weighed and counted with a Geiger counter. The data presented in Table 1 give the activity of the various tissues, expressed as percentage of the control plants, at 8 and 24 hours after spraying with 2,4–D. During the first few hours after treatment with 2,4–D there was a large increase in the uptake of potassium by the treated plants. However, at the end of 24 hours after treatment the reverse was true in that the 2,4–D treatment had greatly inhibited the uptake of potassium.

Table 1. **Effect of 2,4–D on the uptake and distribution of mineral nutrients from the soil by bean plants at various intervals after treatment. Data expressed as percentage of controls.**

Tissue samples	Potassium		Chlorine		Calcium		Sulfate	
	8 hrs.	24 hrs.	12 hrs.	48 hrs.	6 hrs.	48 hrs.	3 hrs.	24 hrs.
Primary leaf blade No. 1..	417	64	307	30	392	489	114	46
Primary leaf blade No. 2..	597	52	160	35	149	152	107	35
Petiole No. 1.....	409	49	438	116	446	423	29	39
Petiole No. 2.....	388	26	315	86	285	173	36	52
Shoot tip.....	213	29	291	31	510	201	53	29
Epicotyl.....	273	50	185	54	179	243	135	70
Hypocotyl.....	309	71	30	61	400	302	114	61

Chlorine

The effect of 2,4–D on the uptake of chlorine was also studied by means of a radioactive isotope of chlorine (Cl^{36}). Immediately after spraying the experimental plants with a solution containing 100 mg./l of 2,4–D and 0.5% Dreft, 20 ml of solution containing KCl^{36} were added to each pot of the control and treated plants. The activity of this solution of Cl^{36} was equal to 2300 counts per minute per 50 lambda of solution. The activity of the various plant tissues, expressed as percentage of the control plants, is presented in Table 1 for samples taken at the end of 12 and 48 hours. Here again, as in the experiment with potassium, there was a marked increase in the uptake of chlorine by the treated plants during the first 12 hours. However, by the end of 48 hours the control plants contained approximately twice as much chlorine as did the treated plants, showing an inhibitory effect of treatment with 2,4–D on the absorption of chlorine from the soil.

Calcium

The effect of 2,4–D on the uptake of calcium from the soil was studied by using $Ca^{45}Cl_2$. The treated plants were sprayed to run-off with a solution of 100 mg/l of 2,4–D containing 0.5% Dreft. Immediately after spraying, 10 ml of solution containing 93 microcuries of Ca^{45} were added to each pot of the treated and control plants. The results at the end of 6 and 48 hours are shown in Table 1. During the first 6 hours, uptake of calcium by the 2,4–D treated plants was greatly stimulated. This stimulatory effect continued for a number of hours and even at the end of 48 hours the treated plants contained considerably more calcium than did the controls. However, at the end of the 48 hour sampling period, it became evident that 2,4–D was beginning to inhibit the uptake of calcium in most of the tissues, although the percentage increase in the leaf blades of the treated plants had not at this time dropped below the level as determined at the 6 hour sampling.

Sulfur

The uptake of sulfur was studied by adding a solution of $H_2S^{35}O_4$ to the soil of each pot immediately after spraying the treated plants with 2,4–D. Ten ml of solution with an activity of 280 counts per minute per lambda were added to each pot. The results of the 3 and 24 hour sampling are shown in Table 1. Initially there was a small increase in the amount of sulfur in the stem and leaf blade tissues of the treated plants. The stimulatory effect of 2,4–D on the initial uptake of sulfate was very small, as compared to that observed for potassium, chlorine and calcium. At the end of 24 hours, 2,4–D had greatly inhibited the uptake of sulfate from the soil.

DISCUSSION

Shortly after the application of 2,4–D to bean plants, there was a marked increase in the uptake of mineral nutrients from the soil. This increase was especially noticeable in the case of the monovalent potassium and chloride ions and the divalent calcium ions. There

was also a slight increase in the uptake of the divalent sulfate ion. After this initial stimulation of mineral uptake, however, 2,4–D treatment resulted in a very marked inhibition in the uptake of minerals from the soil. This inhibitory effect usually became evident at the end of approximately 24 hours after spraying the plants. This inhibitory effect was less evident in the case of calcium although the treated plants did show an inhibition in the uptake of this ion at the end of 48 hours.

The changes in the uptake of mineral ions from the soil observed in these experiments are probably of a secondary nature and not directly related to the primary herbicidal action of 2,4–D. These results, however, might be correlated with the influence of 2,4–D on respiration as reported in the literature. It has been shown (2, 6) that low concentrations of 2,4–D will stimulate respiration in a number of tissues, while higher concentrations will inhibit respiration of these same tissues. Shortly after spraying a plant with 2,4–D, a small amount of this material is translocated to the root system where it may bring about a stimulation of respiration. If this increased respiration is actually capable of being used for ion uptake, there will be an increase in the absorption and uptake of minerals from the soil. However, when the amount of 2,4–D translocated from the foliage to the root system reaches a certain concentration, respiration will be inhibited and, in turn, there may be a decrease in the uptake of minerals from the soil.

SUMMARY

The application of 2,4–D to the foliage of bean plants resulted in an initial increase in the uptake of minerals from the soil. After a period of time, however, 2,4–D treatment resulted in an inhibition of mineral uptake. These results are discussed in relation to the effect of 2,4–D on plant respiration.

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Influence of Light on the Effect of 3–*p*-(Chlorophenyl)–1, 1–Dimethylurea on Plants[1]

WM. HAROLD MINSHALL

INTRODUCTION

IN symptomatological studies with 3–(*p*-chlorophenyl)–1,1–dimethylurea (monuron[2] or CMU) it was found that light intensity had an effect on the type of symptom and on the extent of the injury produced by this chemical. This note is published to direct attention to the influence of light in the herbicidal action of monuron.

It has been shown previously (3) that monuron moved in the transpiration stream of plants. Light, as one of the factors affecting transpiration, could influence the uptake and movement of monuron within plants. This influence in turn would affect symptom development. Light, however, has produced effects quite separate from any influence on transpiration and it is with those effects not related to transpiration or uptake that the present paper is concerned.

Figure 1. Effect of 0, 25, 50, 100, 200, 400 and 800 micrograms monuron per gram fresh weight on excised leaves of two-week-old bean plants grown in greenhouse under slatted shades (top row) and out-of-doors in full sunlight (bottom row).

METHODS AND RESULTS

Effect of light prior to treatment

In September, plants of kidney bean (*Phaseolus vulgaris* L., var. Black Valentine) were grown in the greenhouse under slatted shades

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[2]Common name accepted by the Term. Com. of the WSA.

at approximately 3,000 ft-c. of light and out-of-doors in full sunlight at 10,000 ft-c. of light. When the plants were two weeks old the primary leaves were excised and the cut ends of the petioles were dipped into water solutions of monuron at 600 ft-c. of fluorescent light and 76° F. The absorption was followed by periodically weighing the leaves and solutions, and when the required weight was reached to give a calculated content of monuron per gram fresh weight of leaf, the leaves were transferred to water. Following this absorption the leaves were held at a 16 hour day of 700 ft-c. of fluorescent light, 85° F day temperature, and 75° F night temperature. From Figure 1 it is evident that to produce extensive necrosis sun leaves require a higher internal concentration per unit weight than do shade leaves. This difference in susceptibility to monuron between sun and shade leaves was less pronounced in leaves from 4- or 5-week-old plants than it was in leaves from 2-week-old plants.

Effect of light during treatment

Two-week-old potted bean plants that were being grown under slatted shades in the greenhouse in August were watered from the bottom for 7 days with 8 ppm of monuron. On the eighth day one pot of plants was placed in full sunlight at 10,000 ft-c. while a second pot remained under the slatted shades at 3,000 ft-c. Figure 2 photographed at 9 am of the ninth day illustrates the increased injury and

Figure 2. Effect of sunlight on the development of monuron symptoms. The plants to the right were in sun for 1 day, while the plants to the left remained in partial shade. Details of treatment are in text.

the development of irreversible wilt in the leaves of the plant exposed to sunlight. From the foregoing it is evident that during treatment with monuron, sunshine following several cloudy days can produce startling effects.

Effect of light after treatment

Excised primary leaves from three and one-half week-old bean plants grown in greenhouse under slatted shades in July had the cut ends of their petioles placed in 32 ppm monuron until the leaves had taken up approximately 25 micrograms per gram fresh weight. After absorption of monuron one-half of the leaves were exposed to 600 ft-c. continuous fluorescent light in the laboratory while the other half were exposed to full sunlight in the greenhouse. As will be seen in Figure 3, extensive necrosis of the silver blotch type developed on the leaves exposed to sunlight, but very little injury developed on those leaves exposed to 600 ft-c. of light.

Excised leaves from 4-week-old bean plants grown in the greenhouse in February had their petioles dipped into monuron solution until they had absorbed approximately 125 micrograms of monuron per gram fresh weight. Following treatment the leaves were held for symptom development at (A) 3 ft-c. of light and (B) 1,000 ft-c. of light. Seven days after treatment the leaves held at 1,000 ft-c. of light had approximately 25–30% of their area brown and necrotic from watersoak blotch, but those held at 3 ft-c. had only 2–3% of their area affected by a greyish-coloured water-soak blotch. This difference in extent of injury under the two light intensities was produced by leaves which had their uptake under such conditions as 1 hour of 1,000 ft-c. incandescent light, 2 hours of 1,000 ft-c. fluorescent light, and 12 hours of 3 ft-c. fluorescent light. Therefore, although light intensity during uptake affected the rate of absorption, in leaves which had attained equal internal concentrations under these diverse conditions, the light intensity during uptake did not affect the extent of subsequent symptom development.

DISCUSSION

Although the action of light is emphasized in this paper, it was not the only environmental factor that varied. For the most part a high light intensity was paralleled by a high temperature and a low relative humidity. These latter two factors also affect life processes but in the present experiments the changes which occurred in temperature and humidity were determined primarily by the different light intensities. Light, therefore, is considered the determinant factor for the effects described and for this reason the different environments were given mainly in terms of light intensity.

From the results presented it is evident that light has an effect on the extent of visible injury from applications of monuron to plants and that certain aspects of this effect may be exerted either before treatment or after treatment. The implications of this influence of light are obvious to workers assessing the results of field plot

trials since exposure site, degree of shading, and season in which growth is made can affect the extent and under certain circumstances the type of injury that will develop from monuron treatments. Undoubtedly the diversity of results reported from field plot trials (2) is due in part to the influence of light intensity.

The toxic action of monuron as described in this paper may involve at least two types of action, namely (A) an interference with the supply of water; and (B) a direct participation of light. Insufficient work has been carried out to adequately discuss these toxic actions, but brief mention will be made of their implications.

The sudden appearance of irreversible wilt on the transference of a treated plant from shade to sunlight (Figure 2) supports the suggestion that there may have been an interference with the movement of water to the leaves when the plant was placed under conditions of high water stress. "Plugging" of xylem vessels in plants treated with monuron has been reported by Christoph and Fisk (1), and has been observed on occasion in our experiments. If extensive, such "plugging" could restrict the movement of water and produce wilt. The development of xylem "plugging" from monuron treatment requires investigation.

The development of silver blotch in sunlight (Figure 3) and the effect of light intensity on the extent of injury indicates that light may enter directly into the toxic action of monuron. This effect of light suggests that those physiological processes in which light plays a part should be investigated for possible implication in the mode of action of monuron.

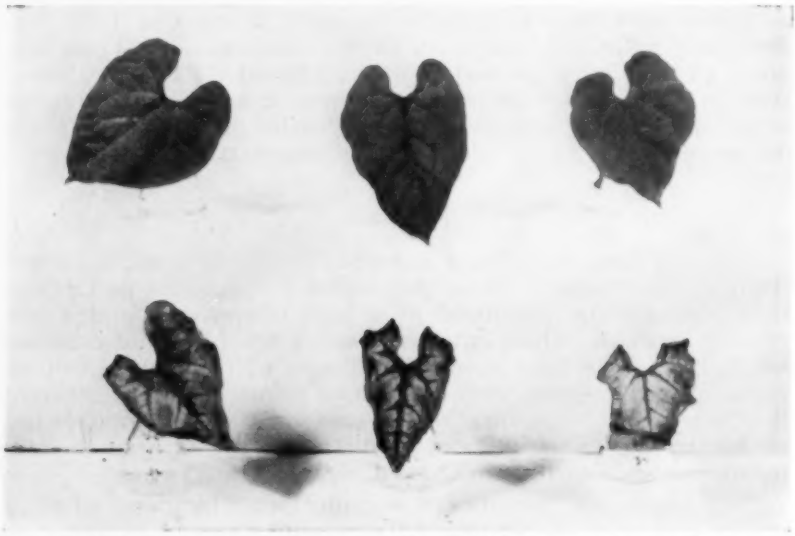

Figure 3. Effect of sunlight (bottom row) and 600 ft-c. continuous fluorescent light (top row) on symptom development in bean leaves containing 25 micrograms monuron per gram leaf. Photographed 8 days after treatment. Columns are paired leaves from the same plant.

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Aspects of the Decomposition and Utilization of Maleic Hydrazide by Bacteria

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MALEIC hydrazide (MH) or 1,2–dihydropyridazine–3,6–dione is an organic plant growth regulator which has been found useful in preventing sucker formation in flue-cured tobacco, in preventing sprouting of stored vegetables, and in inhibiting the growth of some weeds and grasses (4). The compound can be synthesized from hydrazine and maleic acid (1) or by reacting hydrazine hydrate and maleic anhydride.[2] The commercial product, MH–30, is made by reacting MH with diethanolamine (DEA), and contains 58 per cent active ingredient, the remainder being classified as inert ingredients.

In any use of organic chemicals in agriculture the possible toxicity of them to the microorganisms of the environment is extremely important, but one should not be unaware of the other inherent relation between the chemicals and the microorganisms, i.e., the ability of the microorganisms to modify the chemical.

In regard to MH–30 Nickell and English (2) have shown that at commonly used field rates this agent did not markedly harm their test bacteria. No work has been seen that treats with the ability of the microorganisms to modify the chemical. This study was undertaken to investigate the action of some bacteria upon MH and to relate such action to the retention of the phytotoxic properties of the agent.

MATERIALS AND METHODS

Treatment of soil with MH and some of its components. To test the action of MH on soil microorganisms, small plots of soil in a sugar cane field were isolated by driving large tin cans with both ends removed into the ground. Each of the cans contained about 5 kilograms of soil.

The rate of application of the chemicals to the plots of soil were based on results previously secured by the use of certain pure cultures of bacteria in their relation to MH–30, or to two of its components, and not on the commercially used rates for MH–30. Four different solutions in 100 ml amounts were applied at weekly intervals. One can received sterile distilled water; another received 1160 ppm of the commercial (Naugatuck) diethanolamine salt of MH (MH–30); the third received 3000 ppm diethanolamine (DEA); and the last received 35 ppm hydrazine hydrate (HH). After four such treatments had been made, samples were taken and plate counts were made of each plot using each of the following media:

Control medium. Glucose, 1.0 g; peptone, 1.0 g; agar, 15.0 g; mineral salts solution[3], 1000 ml.

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[2]Zukel, J. W. Personal communication, 1954.

[3]0.5 g $MgSO_4$, 0.25 g KH_2PO_4, a trace of $FeSO_4$, and 1000 ml tap water.

MH–30 medium. MH–30, 0.55 g; agar, 15.0 g; mineral salts solution, 1000 ml.

DEA medium. DEA, 0.5 g; agar, 15.0 g; mineral salts solution, 1000 ml.

HH medium. HH, 0.17 g; glucose, 1.0 g; agar, 15.0 g; mineral salts solution, 1000 ml.

Growth of bacteria in MH–30 and its components. A number of colonies from the MH–30-treated soil plated in the MH–30 agar were picked and purified for further study. These cultures, and several others previously isolated from non-sterile water solutions of MH–30, were grown in various concentration and combinations of MH–30 and some of its components in the mineral salts solution in an attempt to determine what moieties of the MH–30 molecule were most liable to bacterial attack.

Gum formation in MH–30 and glucose. Several of the isolates studied formed a gum when grown in liquid media containing MH–30 and glucose. Selected cultures of these were grown in liquid media containing various concentrations of MH–30 with 2500 ppm glucose and the mineral salts solution. The viscosities of these media after bacterial growth were determined by use of the Cannon modification of the Ostwald viscometer. The time in seconds required for the flow of the control or test liquid between the two calibrations on the viscometer was recorded. The "Z" values were calculated from these readings by dividing the viscosity of the medium following growth of the bacteria (Tx) by the viscosity of the uninoculated medium (To).

Detoxification of MH–30. Schoene and Hoffman (3) have shown that tomato plants are quite sensitive to MH. These plants were chosen to serve as a bioassay of the bacterial detoxification of MH–30. Eight solutions were prepared for treating the plants. These were: (1) Tap water, (2) MH–30 (2500 ppm), (3) Decomposition products of 2500 ppm MH–30 after attack by culture C–13, (4) Decomposition products of 2500 ppm MH–30 after attack by a mixed culture, (5) Products formed by culture C–13 after growth in a medium containing glucose and ammonium sulfate, (6) Products formed by the mixed culture after growth in a medium containing glucose and ammonium sulfate, (7) Decomposition products of culture C–13 after growth in a medium containing glucose and MH–30, and (8) Decomposition products of the mixed culture after growth in a medium containing glucose and MH–30.

Tomato seeds were sowed into field soil in a greenhouse. When the young plants had reached a height of 2–5 cm, they were transplanted into small earthen pots where they were allowed to grow for about a week before treatment was commenced. Ten replicates were used for each treatment. Treatment was by spraying to "run-off". Height measurements were taken of the plants on the first day of treatment followed by weekly measurements.

RESULTS AND DISCUSSION

Treatment of soil with MH and some of its components. The results of a representative soil plot test are shown in Table 1. These data do not represent attempts to determine the total numbers of soil microorganisms by means of diverse substrates for particular groups. Rather they express certain relationships between the possible toxicity of the chemicals and the possible stimulatory action of them due to their compositions. When the control medium was used it was found that the numbers of microorganisms in the MH–30- and the DEA-treated soil had increased in the magnitudes of 24-fold and 35-fold respectively when compared with the soil plot which had received only distilled water. Hydrazine hydrate did not appreciably affect the numbers of organisms in the soil.

Table 1. Plate counts on soil treated with MH–30, diethanolamine, and hydrazine hydrate.

Plating media	Treatment of soil plots			
	Distilled water	MH-30	DEA	HH
Control	19,000[1]	440,000	660,000	12,000
MH-30	6,200	100,000	170,000	9,400
DEA	9,800	180,000	470,000	11,000
HH	12	12	38	8

[1]Figures represent thousands of organisms per gram of dry soil.

When the plating medium was the MH–30 agar, the population that was in the MH–30-treated soil was found to contain a large number of organisms which could utilize the MH–30 of the medium as their sole source of carbon and nitrogen. The results also indicate that many organisms of the DEA-treated soil found the environment of the MH–30 agar conducive to their growth. The majority of the organisms from these two soil samples produced yellow, cream, or grayish-white bacterial colonies. Very few molds or *Streptomyces* were present.

When the plating medium was the DEA agar there appeared to be but little difference in the growth supporting ability of it when compared to the MH–30 medium. As MH–30 is the DEA salt of MH this observation is not surprising.

The hydrazine hydrate medium's nitrogen was not as good a source of this element as was the nitrogen of the other three substrates; the number of organisms which grew on it was markedly less and those which grew were almost exclusively molds.

Growth of bacteria in MH–30 and its components. Thirty-two cultures were isolated in this investigation which were apparently able to utilize some component or components of MH–30 in their metabolism. A study was made of the growth of several of these organisms in liquid media containing MH–30 and/or its components in various combinations and concentrations. Several aspects of the growth of these cultures became apparent:

(1) Hydrazine hydrate was toxic to the cultures above 110 ppm.

(2) About 7 days were required before good growth of the cultures occurred in a liquid medium containing only MH–30 as the carbon and nitrogen source. Two of the cultures best able to attack MH–30 were identified as *Alcaligenes faecalis* and *Flavobacterium diffusum*.

(3) Maleic anhydride served nearly as well as a carbon source as did glucose.

(4) Diethanolamine was readily attacked by most of the cultures. It is of interest to note that Nickell and English (2) suggested that this compound might be a toxic agent and thus be responsible for the inhibition they found with their higher concentrations of MH. The present work indicates that DEA, rather than being toxic, served well as a source of nutrients for the test bacteria.

Gum formation in MH–30 and glucose. Growth of several of the cultures in a liquid medium containing MH–30 and glucose resulted in the formation of a gum as shown by changes in the viscosity of the medium. These changes reflect the physiological response of the organism to various concentrations of MH–30 and 2500 ppm of glucose (Figure 1). The lesser amounts of gum at low MH–30 concentrations are due probably to the low nitrogen to carbon ratio, and the lesser viscosities at higher concentrations can, undoubtedly, be attributed to the increasing toxicity of the MH–30 to the bacteria at these levels.

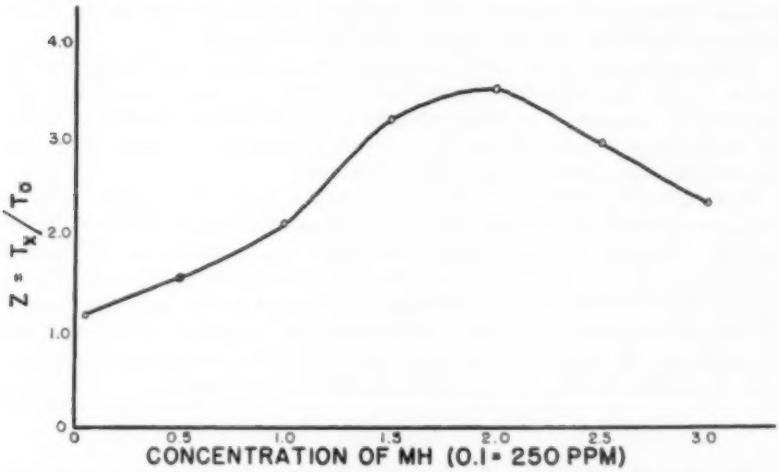

Figure 1. Viscosity curve for *Alcaligenes faecalis* in MH–30 and glucose.

Detoxification of MH–30. Table 2 shows the results of the study of the effects of the decomposition products of MH–30 on tomatoes. The plant controls, which received only water, increased steadily in height until at 28 days they had increased their heights by an average of 104 mm. The MH–30-treated plants, on the other hand, kept

pace briefly but after 28 days had increased in height by only 30 mm, meaning that their growth had been inhibited by 71 per cent as compared with the control plants.

Table 2. **Effects of the products of bacterial growth in MH–30 and in MH–30 and glucose on tomato plants.**

Treatment solution	Average initial height mm	Days after initial treatment					
		7		18		28	
		Average height increase mm	Inhibition %	Average height increase mm	Inhibition %	Average height increase mm	Inhibition %
Plant control	30.6	15.3	—	40.1	—	104.2	—
MH-30	28.4	11.3	26.1	27.9	30.4	30.1	71.1
C-13[1] control	32.5	11.9	22.2	41.6	−4.0	100.1	4.1
Mixed[2] control	39.2	5.1	66.7	33.8	15.7	95.6	8.2
C-13 MH-30	28.7	13.6	11.1	39.0	2.7	51.5	50.6
Mixed MH-30	31.4	10.4	32.0	35.3	12.0	55.5	46.7
C-13; MH-30, glucose	30.8	15.5	−1.3	36.7	11.0	47.5	54.4
Mixed; MH-30, glucose	30.3	11.0	28.1	37.9	5.5	60.9	41.5

[1]C-13: the pure culture of *Alcaligenes faecalis*.
[2]Mixed: a mixture of pure cultures of bacteria isolated from MH-30 enriched soil.

The plants treated with the 2500 ppm MH–30 solutions in which bacteria had been grown showed a 51 per cent inhibition in the case of the pure culture and a 47 per cent inhibition of growth with the mixed cultures. The important aspect of this is that a certain amount of detoxification of MH–30 did take place due to bacterial action. The only carbon and nitrogen source available to these cultures was that present in the MH–30 molecule.

Two solutions were used as organism controls and from the results shown the cultures themselves did not produce materials of a phytotoxic nature. The gum produced by microbial growth in MH–30 and glucose proved to be no more inhibitory than were the decomposition products of MH–30 alone.

It is felt that this detoxification, shown here with pure cultures of bacteria and MH, illustrates a very important facet of the relation of the diverse organic chemicals used in agriculture to microorganisms. When the chemical contains elements capable of serving as sources of energy or components capable of being used for growth by the microorganisms, then that chemical is going to be modified irrespective of whether this decomposition has desirable or undesirable features insofar as the agriculturist is concerned.

SUMMARY

Bacteria capable of utilizing the diethanolamine salt of maleic hydrazide have been isolated both from soil treated with the chemical and from water solutions of it. Two of the organisms have been identified as *Alcaligenes faecalis* and *Flavobacterium diffusum*.

Diethanolamine served as a good carbon and nitrogen source for the organisms tested.

Alcaligenes faecalis formed a gum when grown in a liquid medi-

um containing maleic hydrazide and 2500 ppm glucose. The optimum concentration of maleic hydrazide for gum formation was near 5000 ppm.

The phytotoxic properties of the diethanolamine salt of maleic hydrazide for tomatoes were lessened following bacterial growth.

ACKNOWLEDGMENT

The authors wish to acknowledge with thanks the generous supply of chemicals made available by the Naugatuck Chemical Division of United States Rubber Company.

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Post-transplanting Weed Control of Celery in Organic Soils

V. L. Guzman[1]

The average annual celery production in Florida for the last five years has been 10,080 acres, most of which is grown in organic soils, with a value of 14 million dollars (1). Florida produces approximately 54 per cent of the celery marketed in the nation during the winter and spring months (2).

Celery growing is expensive, and hand weeding is one of the costly operations. Control of weeds in the seedbeds is accomplished by soil fumigants, if used, and to a large extent by stoddard solvent supplemented by a few hand weedings of resistant weeds. After the plants are set in the field two to four hand weedings in the row may be necessary before harvest. The cost of hand weeding (scratching and pulling weeds) may vary widely, but a conservative average is $30.00 per acre. Other complicating factors are the scarcity of hand labor in the fall and late spring and prevalence of weather conditions conducive for rapid weed growth. The objective of this study, therefore, was to find an effective herbicide for controlling weeds after the celery is transplanted in the field.

Work conducted in the past at this Station indicated that stoddard solvent applied on transplanted celery causes bud injury (3). As a result, no herbicides have been used on transplanted celery. Promising results however were obtained in 1954 and 1955 with herbicides for weeding celery. Therefore in the spring and fall of 1955 experiments 1 and 2, respectively, were conducted using the Summer Pascal variety.

The basic idea for experiment 1 was to use herbicides to which celery is quite tolerant and to direct the spray from the side to the base of the celery plants touching the lower two inches of the stem, to avoid bud injury as much as possible.

The basic idea for experiment 2 was to use herbicides which had shown to have little or no effect on the celery plants, but were effective as pre-emergence weed suppressors. Since celery is machine transplanted in clean freshly prepared ground, the chemicals, if applied soon after transplanting, could work as pre-emergence weed toxicants. Furthermore, the effect of the herbicidal spray on the celery plants would be minimized by the washing action of routine overhead irrigation. This water would also provide to the upper soil layer the high moisture content necessary in most cases for effective pre-emergence weed control.

Materials and Methods

Herbicides, expressed in pounds of active ingredient per acre, were diluted in 30 gallons of solution except when applied as pellets. In experiment 1, they were applied directionally one month

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after transplanting on March 25, 1955. In experiment 2, the herbicides were applied as an over-all application after transplanting the celery on September 30, 1955. The applications were followed immediately by routine overhead irrigation. This operation was continued for half an hour after the last chemical was applied. Samples of the upper inch of soil were taken for moisture determination three hours after irrigation was stopped.

Plots were single rows 30 feet long, three and two feet apart respectively for experiments 1 and 2. A Latin square design was used for experiment 1 and randomized blocks with six replications for experiment 2.

Herbicides used were, isopropyl N-(3–chlorophenyl)carbamate (CIPC), stoddard solvent (petroleum distillate, also called mineral spirits), hydrin (mixture of aromatic hydrocarbons), 2–chloro–N,N–diallylacetamide (CDAA), 2–chloro–N,N–diethylacetamide (CDEA), and 2–chloroallyl diethyldithiocarbamate (CDEC).

The entire field of experiment 1 was machine cultivated twice in the middles. One hand weeding of large weeds in the row was necessary before application of the herbicides. The check plots received one additional hoeing a month later.

The plots in experiment 2 were hand weeded as necessary and the time spent in weeding each treatment was recorded. The middles were machine cultivated once.

At harvest the celery was sorted according to size in number of dozens of marketable stalks to fill a crate. Thus, a 2-dozen crate contained larger plants and commanded in general a better price than a 4-dozen crate. Also yields in pounds were recorded. Significance was determined by Duncan's multiple range and multiple F tests.

RESULTS

Experiment 1. Directional application of herbicides.

The control of weeds and yields as a result of the herbicidal treatments are given in Table 1. CIPC gave the best control of weeds to harvest (two months). The effect of the contact herbicides such as stoddard solvent and hydrin was excellent for three weeks. Thereafter grass weeds began to grow. At harvest-time the check, hydrin

Table 1. Herbicidal treatments applied directionally to celery and their effects on weed control, number and weight of celery stalks.

Treatments	Lbs/A	Weed control[1]	Yields of marketable celery per 180 feet of row	
			Number of stalks[2]	Weight (lbs.)
CIPC in stoddard solvent	8	8	248 a	459.0
CIPC (pellets)	10	9	264 bcd	518.3
Stoddard solvent	30	6	266 bcd	502.1
CIPC in water	8	9	276 cde	510.0
Hydrin	10 gal.	6	280 de	535.2
Cultivated (check)	—	6	298 e	539.8
Differences at .05	—	–	S	NS

[1]Zero, no control; 10, perfect control.
[2]Values not adjacent to the same letter are significantly different.

and stoddard solvent plots were the weediest, while the CIPC plots remained fairly clean.

The liquid application of eight pounds of CIPC produced light burning of the celery leaves. CIPC in stoddard solvent caused a temporary check in the growth of the celery plants in addition to the light burning. At harvest time these plants appeared to be similar in size to those of the check.

No ill effects from any of the herbicidal treatments were noticed on the growing points of the celery plants. This was probably due to the directional application of the chemicals, which helped prevent excess wetting of the growing points. The number of marketable stalks, which commercially is the important criteria of classification, was significantly reduced by CIPC applied as pellets, in solvent, or by solvent when used by itself. The reduction in the number of marketable stalks was also reflected in a decrease in weight although the differences in weight were not significant (Table 1).

Experiment 2. Over-all application of herbicides followed by irrigation.

It appeared that the celery was tolerant to the chemicals used or that the amount of irrigation applied (55 per cent of water in the upper inch of soil) helped to wash most of the herbicides from the leaves of the plants. Probably there was a combined effect of both since no ill effects were noticeable during the growing period (Table 2, last column).

Table 2. **Effect of over-all application of herbicides, followed by overhead irrigation, on the celery plants and weeds.**

Treatments	Lbs/A	Weed control index[1]	Man hours/A for hoeing[2]	Plant appearance[3]
Cultivated check	—	5	42.0 a	1.1
CIPC	10	9	11.4 b	1.3
CDEA	8	8	9.9 b	1.3
CIPC pellets	10	8	9.7 b	1.3
CDEC	4	8	8.4 b	1.0
CDAA	8	9	7.5 b	1.0
CDEC	8	10	6.9 b	1.1
CIPC + CDEC	4 + 4	10	6.7 b	1.3
Differences at .05			S	NS

[1]0, no control; 10, excellent control (taken one month after treatment and before second hand weeding of check plots).

[2]Values not adjacent to the same letter are significantly different.

[3]1, normal plants; 2, slight check in growth; 3, severe check in growth (taken 45 days after treatment).

Weed control was excellent with all the herbicidal treatments for over a month (Figure 1). However, some hand weeding was necessary before harvest. Weed control indexes in Table 2 indicate the average relative control obtained before the second hand weeding of the check plots. Man hours used per treatment for weeding until harvest are also given in Table 2 and the orthogonal comparisons are given in Table 3. A significantly greater number of man hours was used for weeding the check plots than for those treated with herbicides. It is probable that chemical weed control

in celery has an economical advantage over hand weeding. Significant orthogonal comparisons (Table 3) indicate that more efficient control of weeds was obtained with CDEC and the combination of CDEC with CIPC than with CIPC or CDEA alone.

Table 3. Orthogonal comparisons for man hours per acre for hoeing.

Comparison	Sums of squares	Mean square[1]
Check vs. all chemicals	160.329	356.00
CIPC spray vs. CDEC and CDEC + CIPC	2.350	5.20
CIPC spray and pellets vs. CDEC and CDEC + CIPC	2.340	5.22
CIPC spray and CDEA vs. CDEC and CDEC + CIPC	2.470	5.48

[1]F = 4.12 at the 5 per cent level.

Figure 1. Row on the right is from the check immediately before hand hoeing. The left row shows the excellent control of weeds obtained with 8 pounds of CDEC. Similar results were obtained with CDAA, CIPC and a mixture of CDEC and CIPC.

Yields of crates per acre of marketable celery calculated from the number of stalks of each grade are given in Table 4. Table 5 shows the total weight of the marketable celery stalks from each of the treatments. The differences are not significant from the check except in the case of total crates (last column in Table 4) in which a significant reduction in the number of crates due to the use of CIPC pellets occurred in comparison with the treatment receiving CIPC in water. However, over-all results obtained seem to indicate that the majority of the herbicides used and the method of application did not have significant effect on the yields of the crop. The use of chemicals also might have some advantage over hand weeding due to the large difference in man hours needed for hoeing the check plots. Quality of the crop was not affected by any of the treatments.

Table 4. Yields, in crates per acre of marketable celery, as affected by various herbicidal treatments applied soon after transplanting.

Treatments	Lbs/A	Crates per acre					
		2 doz.	2.5 doz.	3 doz.	4–8 doz.	Sub-total for 2, 2.5 & 3 doz.	Total crates[1]
CIPC pellets	10	191.3	153.1	164.8	239.1	509.2	788.3 a
CIPC + CDEC	4 + 4	110.8	177.3	215.3	315.3	503.3	818.6 ab
CDEA	8	186.3	153.1	232.1	255.0	571.7	826.5 ab
CDAA	8	216.5	209.5	195.1	206.8	621.1	827.9 ab
CDEC	8	221.5	141.0	225.4	271.1	587.9	858.9 ab
Cultivated check	—	221.5	145.0	178.3	329.3	544.8	874.0 ab
CDEC	4	176.2	165.2	248.9	293.2	590.3	883.5 ab
CIPC	10	267.0	173.3	215.3	263.0	655.3	918.4 b
Differences at .05		NS	NS	NS	NS	NS	S

[1]Values not adjacent to the same letter are significantly different.

Table 5. Yields of marketable celery following post-transplanting application of herbicides.

Treatments	Lbs/A	Yield in pounds per 180 feet of row	
		2, 2.5 and 3 doz. crates	Total from 2 to 8 doz. crates
CIPC + CDEC	4 + 4	206.8	339.1
CIPC pellets	10	210.8	333.0
CDEA	8	223.8	349.2
Cultivated check	—	233.7	393.2
CDEC	4	240.9	371.9
CDEC	8	249.3	365.9
CDAA	8	268.4	372.5
CIPC	10	284.5	408.5
Differences at .05		NS	NS

General Discussion

The significant reduction in number of marketable celery stalks when using stoddard solvent for weed control can be in part attributed to light burning of the leaves, probably due to the relatively high temperatures at the time of application and afterwards (86° F at noon). The celery plants at one month after transplanting were perhaps slightly too large, and as a result of the treatment the weaker were damaged. These plants failed to attain marketable size at harvest.

Yield reduction by the CIPC pellets may be due to the high rate used (ten pounds per acre) or to the retention of the herbicide in toxic amount in the base of the leaf petiole. This in turn could have prevented some plants from reaching marketable size at harvest, since the stand of the plants was nearly perfect in all the treatments.

Although some contributing factors could have decreased the effect of the chemicals on the celery plants, such as the washing action of overhead irrigation, there is little doubt that celery is highly tolerant to most of the herbicides used.

Summary

In experiment 1, the directional application of herbicides one month after transplanting appeared to reduce yields of celery when

CIPC in stoddard solvent, CIPC pellets or stoddard solvent alone were used. CIPC in water solution at a rate of eight pounds per acre gave good weed control with no yield reduction. In experiment 2, the herbicides were applied immediately after transplanting the celery plants, followed by overhead irrigation. Excellent weed control was obtained with CDAA, CDEC, and with a mixture of CIPC with the latter. No significant yield reduction from the check occurred, but a significantly higher number of man hours was required for hoeing the check plots than for those treated with herbicides.

ACKNOWLEDGMENTS

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Weights of Seeds and Numbers per Plant[1]

O. A. Stevens[2]

The present paper is supplementary to one previously published (3) which received more comment than had been expected. In the meantime Salisbury's book (2) appeared in which reference was made to the paucity of data on the subject and many records from the previous paper were quoted. Salisbury made statistical and ecological studies of various species in Great Britain.

Methods of collection have been the same as for the earlier report (3). In most cases a single plant, judged to be of average size and growing where competition was low, was harvested at maturity or when a maximum number of seeds could be obtained. The plants were air dried for two weeks or more, threshed and cleaned to remove immature seeds, empty florets, etc. In some cases *(Epilobium, Pyrola),* visual examination had to replace the usual cleaning.

This method serves well for species the seeds of which are retained until all are mature. For species in which ripening extends over a considerable period and seeds are shed as soon as mature, only a part of the total number can be secured at a single collection. In most cases that number is given, with footnotes to indicate that more would have developed, or if some had already dropped. As noted in the previous report (3) the total yield for these plants might be estimated at twice as many if some had dropped or had not matured or four times as many if both factors prevailed.

In a few cases daily collections were made or *(Lactuca scariola, L. biennis)* heads were counted and total number estimated. In some plants seeds were extensively damaged by insects and this is noted. In most cases the total number listed is that of good seeds only for one plant. In those groups where seed is not separated readily from fruit the weights are usually of the fruit or parts thereof, such as caryopsis with lemma and palea, achenes, nutlets or mericarps.

For perennials which increase in area, a single stalk was usually taken. The propriety of choosing an "average" plant has been discussed by Salisbury (2) who sought to obtain average yields from a large number of individuals. However, conditions vary so widely that averages would be valid only for the conditions under which samples were taken. Production by occasional plants that survive in fields is an important item which is often overlooked. Further discussion is made under a few species.

Material is from North Dakota unless otherwise indicated. A few species have been duplicated, usually without intention. Specimens from the same lot of a few species have been distributed to several

[1]Contribution from the Department of Botany, North Dakota Agric. College and Exp. Sta. In part a report on Purnell Project No. 146. Published with the approval of the Director.

[2]Formerly Botanist, North Dakota Agric. Exp. Sta. Retired June 30, 1956.

Table 1. Seed weights and production of individual plants.

Species	Wt. 1000 seeds grams	Total number per unit of measure	Unit of measure	Remarks
Sparganiaceae				
Sparganium eurycarpum	46.600	295	1 stem	4 heads
Alismataceae				
Sagittaria cuneata	.235	5,150	1 plant	6 flowers
Gramineae				
Aristida longiseta	3.500	130	1 plant	Awns present
Aristida longiseta	2.000			Awns removed
Bromus inermis	2.900	220	1 stem	
Bromus latiglumis	2.200	1,220	1 plant	
Bromus tectorum	2.400	700	1 plant	
Cinna latifolia	.080	6,400	3 stems	
Deschampsia caespitosa	.200	50	1 plant	
Elymus villosus	3.300	390	1 plant	
Elymus virginicus, var. *submuticus*	4.950	435	1 plant	14 spikes
Eragrostis spectabilis	.103	86,430	1 plant[4]	Kansas
Eragrostis spectabilis	.073			Caryopses
Festuca obtusa	1.100	980	1 plant	
Glyceria grandis	.400	2,550	1 stem	
Glyceria striata	.200	1,650	1 plant	
Leersia oryzoides	1.200	4,240	1 plant	
Lolium persicum[5]	8.650	490	1 plant	
Oryzopsis hymenoides	3.150	280	1 plant	
Phalaris arundinacea	1.100	120	1 stem	
Poa annua	.200	2,050	1 plant	
Poa palustris	.130	2,770	1 plant	Plus many infertile
Puccinellia nuttalliana	.170	3,530	1 plant	
Schedonnardus paniculatus	.300	125	1 plant	
Schedonnardus paniculatus	.340	1,380	1 plant[4]	
Scolochloa festucacea	1.100	1,430	1 stem	
Setaria faberii	1.900	4,030	1 plant	Kansas
Setaria verticillata	1.050	3,180	1 plant	
Sphenopholis obtusata	.090	6,330	1 plant	
Stipa comata	9.040	125	1 plant	Incl. awns
Stipa comata	3.600			Without awns
Stipa spartea	34.400	72	1 plant	Incl. awns
Stipa spartea	16.100			Without awns
Cyperaceae				
Carex cristatella	.240	2,160	1 plant	
Carex filifolia	2.900	232	1 plant	Tuft 1.5 dm., 92 spikes
Carex gracillima	1.350	550	1 plant	
Carex retrorsa	1.260	10,400	1 plant	
Carex stenophylla	1.400	12	1 stem	Av. from 100 spikes
Eriophorum angustifolium	.300	35	1 stem	
Scirpus acutus	1.460	400	1 stem	Av. of 10 panicles
Scirpus cyperinus	.023	100,000	1 plant	Minn., bristles mostly off
Scirpus fluviatilis	8.500	420	1 stem	
Scirpus paludosus	2.730	179	1 stem	
Scirpus validus	.700	1,785	1 stem	Av. of 10 panicles
Araceae				
Acorus calamus	3.720	435	1 stem	
Arisaema atrorubens	21.400	101	1 plant	
Commelinaceae				
Tradescantia occidentalis	3.000	305	1 plant	
Liliaceae				
Allium stellatum	1.800	303	1 plant	3 umbels
Allium textile	2.350	136	1 plant	3 umbels
Allium textile	2.140	56	1 plant	2 umbels
Allium textile	2.560	168	1 plant	
Allium tricoccum	13.250	24	1 plant	Av. of 15
Asparagus officinalis	19.850	2,650	1 stem	
Fritillaria atropurpurea[5]	2.780	72	1 plant	1 capsule
Polygonatum canaliculatum	17.080	270	1 stem	

Table 1. **Seed weights and production of individual plants** *(Continued).*

Species	Wt. 1000 seeds grams	Total number per unit of measure	Unit of measure	Remarks
Smilacina stellata	15.300	16	1 stem	Av. of 10 stalks
Smilax herbacea	30.600	277	1 plant	4 umbels
Trillium cernuum	2.200	106	1 plant	
Amaryllidaceae				
Hypoxis hirsuta	.380	300	1 plant	
Urticaceae				
Pilea pumila	.090	660	1 plant	
Polygonaceae				
Eriogonum multiceps[5]	.450	103	1 plant	Plus 90% infertile
Polygonum aviculare	.900	4,600	1 plant[4]	
Polygonum longistylum	2.400	6,000	1 plant[4]	Kansas
Polygonum pensylvanicum	3.250	6,500	1 plant[4]	Kansas
Polygonum prolificum	1.460	652	1 plant[4]	Plus 403 exserted immature
Polygonum prolificum	1.250	———	———	Without calyx
Polygonum punctatum	2.250	5,140	1 plant[4]	Kansas
Rumex alluvialis[6]	1.000	20,000	1 plant	Grown from Kans. seed
Rumex domesticus	.900	63,250	1 plant	
Tovara virginiana	9.900	113	1 stem	Kansas
Chenopodiaceae				
Atriplex glabriuscula	2.380	———	———	Thin yellow
Atriplex glabriuscula	1.000	6,000	1 plant	Black seeds
Axyris amaranthoides	1.540	500	1 plant[4]	84 rounded, 416 flattened
Chenopodium bushianum[7]	1.450	2,170	1 plant	
Chenopodium fremontii[5]	.400	2,800	1 plant[4]	
Chenopodium glaucum	.280	80,000	1 plant	
Chenopodium strictum[7]	.370	114,200	1 plant	Large plant
Chenopodium strictum[7]	.370	50,000	1 plant	Av. plant
Amaranthaceae				
Amaranthus retroflexus	.340	229,175	1 plant[4]	Large plant
Amaranthus retroflexus	———	147	1 plant	Late plant 8 cm. high
Amaranthus retroflexus	.410	313,000	1 sq. yd.	60 plants, 77,000 immature seeds
Aizoaceae				
Mollugo verticillata	.058	15,000	1 plant[4,8]	
Caryophyllaceae				
Arenaria lateriflora	.450	175	———	About 25 stems
Cerastium brachypodum	.058	795	1 plant[4]	
Gypsophila paniculata	.860	13,700	1 plant	Minn.
Lychnis alba	.580	8,440	1 plant	
Lychnis drummondii	.150	6,730	1 plant[8]	
Saponaria vaccaria	7.400	2,570	1 plant	
Silene dichotoma	.860	15,325	1 plant[4]	
Stellaria media	.387	600	1 plant[4]	
Ranunculaceae				
Ranunculus cymbalaria	.073	1,220	———	1 Tuft
Ranunculus macounii	1.740	784	1 plant[4]	
Ranunculus pensylvanicus	.700	11,200	1 plant[4]	
Ranunculus pensylvanicus	.600	2,500	1 plant[4]	
Ranunculus recurvatus	.575	1,600	1 plant	
Ranunculus sceleratus	.260	3,270	1 plant[4,8]	
Thalictrum dasycarpum	2.550	1,600	1 plant	
Berberidaceae				
Caulophyllum thalictroides	121.000	30	1 plant	
Papaveraceae				
Corydalis sempervirens	.460	1,000	1 plant	Minn.
Papaver somniferum	.280	13,800	1 plant	7 fruits
Sanguinaria canadensis	7.260	31	———	1 fruit

Table 1. Seed weights and production of individual plants *(Continued)*.

Species	Wt. 1000 seeds grams	Total number per unit of measure	Unit of measure	Remarks
Cruciferae				
Arabis divaricarpa	.140	3,000	1 plant	
Arabis holboellii	.085	4,590	1 plant	
Arabis holboellii	.110	9,455	1 plant	
Brassica hirta	4.600	3,125	1 plant	
Brassica juncea	1.840	4,780	1 plant	
Brassica nigra	1.500	5,600	1 plant	
Camelina microcarpa	.280	12,820	1 plant[4]	
Camelina microcarpa	.280	5,035	1 plant	
Cardaria draba	2.150	2,300	1 stem	Plus many infertile
Cardaria pubescens	1.000	20	1 stem	Av. 10 stems
Descurainia sophia	.110	842,700	1 sq. yard	
Draba nemorosa	.019	1,340	1 plant	
Draba reptans	.037	1,300	1 plant	
Lepidium sativum	2.150	2,300	1 plant	
Lesquerella alpina[5]	.476	210	1 plant[4]	
Lesquerella ludoviciana	.467	300	1 plant[4]	Herb. Stevens 139
Raphanus raphanistrum	7.650	1,875	1 plant	Grown in garden
Raphanus sativus	8.500	160	1 plant	Wild form
Rorippa islandica, var. *hispida*	.047	18,080	1 plant[4]	
Rorippa obtusa	.075	19,730	1 plant	
Sisymbrium loeselii	.080	37,200	1 plant	
Saxifragaceae				
Heuchera richardsonii	.063	3,300	1 plant	
Ribes sistosum	1.300	1,830	1 plant	
Rosaceae				
Chamaerhodos nuttallii	.270	780	1 plant[4,6]	
Geum aleppicum	1.750	1,000	1 plant	
Geum triflorum	.600	142	1 plant	
Potentilla pensylvanica	.130	15,200	1 plant	
Potentilla pentandra	.047	32,100	1 plant	
Rosa arkansana	12.100	200	1 stem	
Rosa woodsii	10.640	1,140	1 stem	
Leguminosae				
Amorpha fruticosa	9.250	4,070	1 plant	Fruits
Amorpha fruticosa	5.600	———	———	Seeds
Amorpha nana	4.800	2,310	1 plant	Fruits
Amorpha nana	2.450	———	———	Seeds
Amphicarpa bracteata	35.000	130	1 plant	
Astragalus bisculcatus[5]	4.750	1,870	1 plant	Plus 50% weeviled
Astragalus canadensis	1.600	2,125	1 plant	Plus many infertile or weeviled
Astragalus racemosus	4.000	2,800	1 plant	
Astragalus racemosus	4.300	4,400	1 plant	
Astragalus striatus	1.550	3,000	1 plant	
Astragalus tenellus	3.410	117	1 plant	
Desmodium canadense	5.150	2,160	1 plant	
Hedysarum boreale[5]	5.050	———	1 plant	Segments, mostly infertile
Hedysarum boreale	2.240	125	1 plant	Seeds
Lathyrus venosus	37.500	80	1 stem	
Lupinus pusillus[6]	17.600	50	1 plant[4]	
Petalostemum multiflorum	1.200	1,750	1 plant	Kans., plus many infertile
Petalostemum purpureum	1.500	368	1 plant	Plus many infertile
Psoralea argophylla	19.000	53	1 stem	
Thermopsis rhombifolia[6]	15.200	40	1 stem	
Vicia americana	16.400	62	1 stem	
Geraniaceae				
Geranium bicknellii	1.840	87	1 plant[4]	
Geranium carolinianum	1.950	470	1 plant[4]	
Linaceae				
Linum sulcatum	.200	110	1 plant[4]	
Oxalidaceae				
Oxalis violacea	.450	23	1 plant	Av. of 5 plants

Table 1. Seed weights and production of individual plants *(Continued).*

Species	Wt. 1000 seeds grams	Total number per unit of measure	Unit of measure	Remarks
Polygalaceae				
Polygala alba	.700	515	1 plant	Many yet undeveloped
Euphorbiaceae				
Croton monanthogynous	5.760	26	1 plant[4]	Kansas
Euphorbia dictyosperma	1.350	215	1 plant[4]	
Euphorbia dentata	4.650	835	1 plant[4]	Kansas
Euphorbia maculata (nutans)	.330	156	1 plant[4]	Plus 285 immature, Kansas
Euphorbia marginata	14.500	660	1 plant[4]	Kansas
Euphorbia missurica	.600	900	1 plant[4]	Kansas
Malvaceae				
Abutilon theophrasti	8.750	4,300	1 plant[4]	Below average
Hibiscus trionum	3.500	58,600	1 plant	Large plant collected daily
Malva parviflora	3.500	2,130	1 plant	Carpels
Sida spinosa	3.190	510	1 plant[4]	Kans., carpels
Sphaeralcea coccinea	2.100	1,860	1 plant	Carpels, large plant
Violaceae				
Viola nuttallii[5]	2.900	117	1 plant	
Viola pensylvanica	2.430	43	1 plant[4]	
Loasaceae				
Mentzelia decapetala	1.150	4,460	1 plant[4]	Below average
Cactaceae				
Opuntia fragilis	20.850	485	1 plant	One large clump
Opuntia humifusa	29.400			
Lythraceae				
Ammannia coccinea	.020	335,000	1 plant	
Onagraceae				
Epilobium glandulosum	.084	72,600	1 plant[4,5]	
Gaura parviflora	8.100	520	1 plant[4,6]	Kans., fruits
Umbelliferae				
Cryptotaenia canadensis	2.450	270	1 plant	
Cymopterus acaulis	3.020	116	1 plant	
Heracleum maximum	8.000	2,280	1 plant	Aphid damage
Lomatium foeniculaceum	5.100	149	1 plant	
Lomatium macrocarpum[5]	4.400	1,000	1 plant	
Musineon divaricatum[5]	2.350	625	1 plant	
Pastinaca sativa	4.450	6,240	1 plant	
Zizia aurea	2.100	1,120	1 plant	
Pyrolaceae				
Pyrola elliptica	.001	23,000	1 stalk	Av. of 2 stalks, 18 capsules
Primulaceae				
Androsace occidentalis	0.210	700	1 plant	
Lysimachia quadriflora	4.400	55	1 plant	
Gentianaceae				
Gentiana andrewsii	.060	2,400	1 plant	
Asclepiadaceae				
Asclepias incarnata	4.400	1,200	1 plant	
Asclepias ovalifolia	4.150	200	1 plant	
Asclepias speciosa	5.890	630	1 stem	Av. wt. and No.
Asclepias syriaca[9]	5.850	760	1 stem	Av. wt. and No.
Convolvulaceae				
Cuscuta glomerata	1.200	1,960	1 host stem	
Cuscuta gronovii	2.300	22,900	1 clump	On *Chrysanthemum uliginosum*
Evolvulus nuttallianus[5]	4.950	363	1 plant	S. Dakota

Table 1. Seed weights and production of individual plants *(Continued).*

Species	Wt. 1000 seeds grams	Total number per unit of measure	Unit of measure	Remarks
Polemoniaceae				
Collomia linearis	1.260	183	1 plant	
Phlox hoodii[3]	1.000	50	1 plant	
Hydrophyllaceae				
Hydrophyllum virginianum	8.100	60	1 plant	
Phacelia heterophylla[5]	.850	740	1 plant[4]	
Boraginaceae				
Amsinkia idahoensis[5]	1.200	350	1 plant[4]	Herb. Stevens 629
Amsinkia menziesii	1.700	———	———	
Cryptantha bradburiana[5]	1.450	1,870	1 plant	
Cynoglossum boreale	15.400	50	1 plant	
Hackelia americana	1.400	770	1 plant	
Heliotropium curassavicum	2.550	3,035	1 plant[4]	
Lithospermum incisum	4.700	100	1 plant	
Mertensia lanceolata[5]	.960	52	1 plant	
Labiatae				
Hedeoma drummondii[5]	.190	1,340	1 plant[4]	
Lycopus uniflorus	.250	1,360	1 plant	
Physostegia parviflora	1.900	200	1 stem	
Salvia reflexa	1.450	3,560	1 plant[4,9]	
Scrophulariaceae				
Castilleja coccinea	.048	2,710	1 plant	Yellow form
Castilleja coccinea	.035	1,290	1 plant	Yellow form
Castilleja sessiliflora	.100	3,900	1 plant	
Castilleja sessiliflora	.170	1,500	1 plant	
Orthocarpus luteus	.120	1,170	1 plant	
Pedicularis canadensis	.445	1,530	1 stem	
Penstemon angustifolius[5]	1.000	3,730	1 plant	
Penstemon eriantherus[5]	1.620	2,340	1 plant	
Penstemon nitidus[10]	1.500	513	1 plant	
Penstemon nitidus[10]	.900	180	1 plant	
Veronica peregrina	.035	2,650	1 plant[4,9]	
Martyniaceae				
Proboscidia lousianica	30.600	870	1 plant	Colo.
Orobanchaceae				
Orobanche ludoviciana	.0025	240,000	1 plant	
Phrymaceae				
Phryma leptostachya	5.000	70	1 plant	Fruits with calyx
Plantaginaceae				
Plantago eriopoda	.440	500	1 plant	
Plantago eriopoda	.470	1,570	1 plant	
Plantago indica	1.500	100	1 plant	
Rubiaceae				
Galium aparine	7.600	105	1 plant	
Campanulaceae				
Lobelia siphilitica	.024	8,100	1 plant	
Compositae				
Agoseris cuspidata	2.090	105	1 plant	2 heads
Agoseris glauca	1.820	137	1 plant	4 heads
Aster brachyactis	.170	47,000	1 plant	
Aster hesperius	.260	10,000	1 stem	
Aster umbellatus	.575	4,000	1 plant	Pappus present
Aster umbellatus	.500	———	———	Pappus removed
Carduus crispus	1.600	700	1 plant[4]	
Centaurea repens	4.600	128	1 plant	Plus 80% infertile
Cichorium intybus	.800	4,600	1 plant	Wis.

Table 1. **Seed weights and production of individual plants *(Concluded).***

Species	Wt. 1000 seeds grams	Total number per unit of measure	Unit of measure	Remarks
Cirsium altissimum	5.500	55,120	1 plant[4]	
Circium undulatum, var. *megacephalum*	5.300	136	1 plant	5 heads, plus 50% weeviled
Dyssodia papposa	.550	420	1 plant	Kans.
Erigeron canadensis	.052	32,000	1 plant	Incl. 84% immature
Eupatorium maculatum	.390	2,700	1 stem	
Gaillardia pulchella	2.250	1,730	1 plant	
Helenium autumnale	.330	125	1 plant	Plus 90% weeviled
Helianthus maximiliani	1.700	9,120	1 plant	4 or 5 stems
Lactuca biennis	.900	3,600	1 plant	Est. total
Liatris aspera	1.100	145	1 plant	Plus 70% infertile or weeviled
Liatris punctata	4.660	58	1 plant	Plus 90% infertile or weeviled
Liatris pycnostachya	1.100	330	1 plant	Plus 60% infertile or immature
Petasites sagittatus	.036	550	1 stem	
Ratibida pinnata	.720	4,300	1 plant	Minn.
Senecio integerrimus	.760	760	1 plant	
Silphium perfoliatum	6.850	295	1 stem	
Solidago canadensis, var. *gilvocanescens*	.100	16,500	1 stem	
Solidago mollis	.175	4,850	1 stem	
Taraxacum erythrospermum	.410	20,000	1 plant	Large plant
Taraxacum erythrospermum	.370			Pappus removed
Taraxacum officinale	.640	12,000	1 plant	
Taraxacum officinale	.620			Pappus removed
Tragopogon major	6.000	150	1 plant	Outer flowers
Tragopogon major	4.000	330	1 plant	Inner flowers

[3]Hitchcock, A. S., "Manual of the Grasses of the United States", 2nd edition, USDA Misc. Publ. 200, 1950.
[4]Additional seeds not matured.
[5]Harrington, H. D., "Manual of the Plants of Colorado", 1954.
[6]Gates, F. C. and MacGregor, R. L., Trans. Kansas Acad. Sci. 53:186, 1949.
[7]Wahl, H. B., Bartonia 27:1–46, 1954; Stevens, O. A., North Dakota Agr. Exp. Sta. Bimonthly Bul. 17:108–110, 1955.
[8]Additional seeds shattered.
[9]Stevens, O. A., North Dakota Agr. Exp. Sta. Bul. 333, 1945.
[10]Rydberg, P. A., "Flora of the Rocky Mountains and Adjacent Plains", 1922.

large herbaria and collector's numbers of these are cited. Nomenclature follows M. L. Fernald, "Gray's Manual of Botany", 8th. edition, (1950) in most cases. Western species are according to H. D. Harrington, "Manual of the Plants of Colorado" (1954).

Comparison of seed numbers per plant

In the previous paper (3) seed weights were compared with those reported by other workers because of the utility of these in seed analysis. Salisbury (2) also emphasized seed weight. In Table 2 numbers of seeds per plant are shown for species listed by Korsmo (1), Salisbury and Stevens. There seem to be only six that have been reported in all three listings. Where ranges were given by Salisbury the averages are shown and the totals are rounded off.

The numbers found by the three workers probably agree in the main as well as could be expected. Korsmo's figures run low as a rule, apparently because plants under considerable competition were used.[11] In a few cases *(Linaria, Matricaria, Stellaria, Solanum)* they are high. Salisbury mentions 16 stems for his *Linaria*.

[11]Korsmo, E. Private communication in which it was stated that his figures were averages for weeds growing among crop plants. 1931.

Table 2. Numbers of seeds per plant found by three workers.

Species	Authority		
	Kornmo	Salisbury	Stevens
Achillea millefolium	3,300	———	210[12]
Alisma plantago and *A. triviale*	———	36,500	21,200
Arctium minus	1,900	———	31,600
Atriplex patula	3,000	———	16,400
Avena fatua	450	———	250[4]
Berteroa incana	7,300	———	2,530
Brassica kaber	1,200	———	2,700
Brassica hirta	1,800	———	3,125[12]
Capsella bursa-pastoris	21,000	3,700	38,500[4, 8]
Chenopodium album	3,100	———	72,450
Chenopodium glaucum	2,800	———	80,000[12]
Chenopodium rubrum	3,000	250,000	176,300
Chrysanthemum leucanthemum	2,000	2,700	510[12]
Cichorium intybus	6,500	———	4,600[12]
Descurainia sophia	6,000	———	75,650
Echinochloa crusgalli	600	———	7,160[4, 8]
Erigeron canadensis	———	25,000	32,000[12]
Erysimum cheiranthoides	3,750	———	30,500
Galium aparine	360	———	105[12]
Hyoscyamus niger	8,000	6,300	———
Juncus bufonius	———	34,000	5,300
Linaria vulgaris	8,700	31,500	2,280
Malva rotundifolia (*borealis*)	500	———	47,500
Matricaria matricarioides	———	6,400	850
Mentha arvensis	200	———	5,500[12]
Plantago major	21,500	———	36,150
Polygonum aviculare	160	———	6,380[12]
Polygonum convolvulus	170	———	11,900
Polygonum hydropiper	385	———	3,300
Polygonum lapathifolium	825	———	19,300
Polygonum persicaria	500	———	1,550[4]
Ranunculus sceleratus	———	26,500	3,270[4, 8, 12]
Raphanus raphanistrum	160	———	1,875[12]
Rorippa palustris and *R. islandica*	———	13,000	18,000[12]
Rumex acetosella	1,000	———	250[12]
Rumex crispus	3,700	———	29,500
Rumex domesticus	9,000	———	63,250[12]
Rumex maritimus	———	64,000	98,250
Salsola kali	300	———	24,700
Setaria glauca	850	———	6,420[4]
Silene dichotoma	1,100	———	15,325[4, 12]
Solanum nigrum	40,000	8,000	———
Sonchus arvensis	6,400	13,300	9,750[12]
Stachys palustris	240	———	64[12]
Stellaria media	15,000	———	600[4, 12]
Taraxacum officinale	3,000	2,400	12,000[12]
Thlaspi arvense	900	2,000	7,040
Verbascum thapsus	———	136,000	223,000

[4]Additional seeds not matured.
[8]Additional seeds shattered.
[12]One stem.
[13]Reported in present paper; all other in earlier report (3).

NOTES ON INDIVIDUAL SPECIES

Actaea rubra. A 20-year old plant in a flower bed bore 19 racemes with 20 to 40 fruits each.

Amaranthus retroflexus. The small plants grew sparsely in bare garden soil. Late summer was so dry that further growth was prevented. In the square yard of 60 plants only two produced lower branches. The comparisons of this with the large plant is a fair example of what happens under moderate competition compared with unrestricted growth under favorable conditions.

Atriplex glabriuscula. A flourishing colony of this was found in 1954 near a railroad in Fargo, N. Dakota. Another was seen in 1955

about one-half mile from the first but seed production was poor. From the first colony, herbarium material was collected (No. 1507) in early bloom August 27 and fruit September 30. The clusters showed scattered larger fruits the bracts of which averaged 4 mm wide as compared to 2.4 mm for the others. There was some intergradation (maturity?) but the size distribution in the smaller ones followed a normal curve while that of the larger ones was quite irregular. Salisbury (2) reported one to two per cent of the larger seeds in *A. patula*. The present writer (3) had either overlooked or discarded them.

Centaurea repens. Collected in August from stems of previous year but seemed not to have shed.

Polygala alba. This is a species that produces flowers over a considerable period and sheds quickly.

Rumex alluvialis. This was grown from seeds supplied by Rev. S. V. Fraser of Concordia, Kansas. It is probably the same as plants identified by Dr. John W. Moore as *R. odontocarpus* Sandor. This is well established in North Dakota, also in adjacent South Dakota and Minnesota. Both it and *R. domesticus* have been overlooked because of their resemblance to *R. crispus*.

Schedonnardus paniculatus. In one case "average" tufts were found to be separable into many (individuals?). One result is from one of these separations and the other probably from an entire tuft.

Stellaria media. The high number given by Korsmo is surprising. The plants most commonly are much crowded in lawns. The present record was from a garden and it was hard to find a specimen that seemed normally fertile.

Taraxacum erythrospermum. The large plant listed in the Table 1 grew in a garden and ripened 162 heads, averaging 120 fruits each from May 26 to June 6.

Taraxacus officinale. The number of fruits varies greatly according to size of plant. Ten plants in an unused city area produced 7 to 79 (av. 24) heads. The number of fruits per head varied from 100 to 300. The one listed in the Table 1 matured 65 heads, and averaged 124 fruits each, from May 28 to June 2. Yields of 3,700 to 20,800 were given by von Hofsten (4).

Thlaspi arvense. Salisbury (2) calculated an average of 468 seeds per plant from two square yards that the present writer harvested. This would be about one-half as many per plant as Korsmo (1) reported, one-fourth what Salisbury calculated and one-fifteenth what Stevens had reported (3). The square yard samples were taken in fallow ground where there was an even and nearly pure stand but without excessive crowding. Evidently the plants were considerably suppressed. Under extreme crowding a single fruit or none at all is produced. In 1953, plants were harvested in 352 feet of wheat drill rows (equivalent to 176 sq. ft.). There were 189 plants averaging 5.5 fruits each. The largest number of fruits per plant was 22 (about 200 seeds).

Tragopogon major. The figures given were from five heads, a low number. A large plant in the garden produced 154 heads from June 15 to August 18. The inner fruits were thought perhaps infertile but both kinds germinated promptly and completely when tested in a chamber a few days after maturing. The number of flowers per head decreased on later branches. Several heads that flowered July 6–12 averaged 117 fruits plus 8 undeveloped; July 17–23, 76 plus 2; and Aug. 15–18, 53 plus 17.

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2. SALISBURY, E. The reproductive capacity of plants. G. Bell & Sons, London. 1942.
3. STEVENS, O. A. The number and weights of seeds produced by weeds. Amer. Jour. Bot. 19:784–794. 1932.
4. VON HOFSTEN, C. G. Studien över släktet Taraxacum Wigg. Lts. Förlag, Stockholm. 1954.

BRIEF PAPERS

Striga: A Serious Parasitic Weed Found in North Carolina

W. G. WESTMORELAND and G. C. KLINGMAN[1]

DURING early August witchweed *(Striga spp.)* was recognized and tentatively identified in the southeast section of North Carolina. The area of infestation apparently covers about ten square miles. Near Evergreen in Columbus County a field of sandy soil containing over four acres will literally fail to produce enough corn to replant. A part of the same field planted to cotton is practically free of crabgrass. In adjoining Robeson County two more small infested fields have been discovered. The areas in the two counties are some 30 miles apart and are apparently two separate infestations.

No immediate information is available regarding the source of these infestations. It is believed the original introduction occurred about five years ago. This genus of plants is reasonably widespread in the Eastern Hemisphere but is believed to be unreported in the United States prior to these findings. The potential danger to agricultural lands is serious since the species spread primarily through almost microscopic seed, and these infestations are located in an area subject to widespread soil blowing in the spring.

Much is yet to be done to determine its host range on local crop and weed species. It is presently identified as a parasite on corn and crabgrass *(Digitaria spp.)* and is suspected to parasitize a wide range of other grassy species. Evidently host plants can become parasitized within two to three weeks after germination. Injury can result in losses ranging up to complete crop failure. Cotton and cowpeas apparently grow without injury in infested soils.

A research and extension education program based on a limited amount of research information is being launched to cope with the problem.

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News and Notes

R. F. Carlson has joined the staff of Ryukyus University at Okinawa and is working on weed control and cultural problems in horticultural crops. He was formerly in the Dept. of Horticulture, Michigan State University, East Lansing, Michigan.

Floyd M. Ashton accepted a position with the Botany Dept., University of California, Davis, to conduct studies on the control of weeds in row crops. He was formerly with the Hawaiian Sugar Planters' Association in Honolulu.

The next meeting of the California Weed Conference will be held in Fresno, California, January 22–24, 1957. Headquarters will be the Hotel Californian and meetings will be in the Municipal Auditorium.

The Aircraft Research Center of the Texas Engineering Experiment Station conducted its second Agricultural Pilot Training School from November 5 through December 15, 1956 at College Station, Texas. Instruction in flight training, care and service of equipment, pesticide control practices, defoliation and desiccation, and aerial seeding and fertilizing were included.

Robert M. Menges has accepted a position as Horticulturist with the Weed Investigations Section, ARS, USDA. He will cooperate with personnel of the Texas Agricultural Experiment Station located at Weslaco, Texas. Menges received his graduate training at Rutgers University.

The Dept. of Agronomy at Mississippi State College offered a three-weeks short course during June, 1956 entitled "Weeds and Their Control." This course was given mainly for teachers of vocational agriculture and for county agents. The interest in the course was so great that it will be repeated in succeeding years.

Thomas Muzik joined the Agronomy staff at the State College of Washington in September, 1956. He will be in charge of weed research and teaching. Muzik came from a position with the Weed Investigations Section, ARS, USDA, at Puerto Rico.

George Friesen received his Ph.D. degree from the State College of Washington in June, 1956, and is now in charge of weed research and teaching at the University of Manitoba.

The third territory-wide Hawaiian Weed Conference meeting was held on the Island of Kauai on May 24 and 25, 1956. The two-day meeting consisted of formal papers each morning with field trips to plantations or ranches each afternoon. The Conference meeting in 1957 will be on the Island of Oahu, May 23 and 24. Stephen Au is the President of the Conference for 1956–57.

Lyle W. Weldon has been appointed as Agent (Research Agronomist) by the Weed Investigations Section, ARS, USDA, to assist

in weed investigations at the University of Wyoming, Laramie, Wyoming.

Stanford N. Fertig returned to Cornell University in June, 1956, after 18 months at the College of Agriculture, University of the Philippines. In the Philippines he worked with the local staff in setting up a research program on weed control in rice, sugar cane, corn, pastures and on woody plants.

The eleventh annual meeting of the Northeastern Weed Control Conference will be held January 10, 11 and 12, 1957; in New York City at the Sheraton-MacAlpin Hotel. L. L. Danielson, plant physiologist at the Virginia Truck Experiment Station, Norfolk, Virginia, is president of the conference this year.

The 10th annual meeting of the Southern Weed Conference is scheduled to be held in Augusta, Georgia, January 23–25, 1957. All sessions of the conference will be held at the Bon Aire Hotel. W. B. Albert of the South Carolina Agricultural Experiment Station, Clemson, South Carolina, is president of the conference.

Russel L. Nash, who recently received his M.S. degree from South Dakota State College, started work in July, 1956, at the North Platte Experiment station near North Platte, Nebraska. He will be working half-time in weed research and half-time with the Division of Noxious Weeds.

From July 17 to 20, 1956, Kansas State College and the Kansas State Board of Agriculture co-operated in conducting a short course at Manhattan for county weed supervisors. The course included discussions on weed control, classification and identification of plants, and activity of herbicides. About 70 weed workers attended the course.

Vernon Woestemeyer resigned his position as State Weed Supervisor, of the Kansas Board of Agriculture, and joined the staff of the Pacific Coast Borax Company in August, 1956.

Jake Ubel assumed the position of State Weed Supervisor in Kansas in September, 1956. He was previously employed by the Board of Agriculture as Assistant Director of the Marketing Division.

The Noxious Weed Division of the Kansas Board of Agriculture now has three Assistant State Weed Supervisors. John Hutchison and Maynard Scott were previously employed. Gene Heath has been added to fill a new position made available in September, 1956.

D. L. Klingman of the Weed Investigations Section, ARS, USDA, has been transferred to the Plant Industry Station, Beltsville, Maryland in September, 1956. In his new assignment he will be the leader in the Range and Pasture Weeds Project. Klingman was previously stationed at the University of Missouri, Columbia, Missouri.

SUSTAINING MEMBERS

American Chemical Paint Company, Ambler, Pennsylvania
American Cyanamid Company, New York, New York
American Smelting and Refining Co., Central Research Laboratories, South Plainfield, New Jersey
Asplundh Tree Expert Company, Jenkintown, Pennsylvania
Association of American Railroads, Chicago, Illinois
Chemical Insecticide Corp., Brooklyn, New York
Chipman Chemical Company, Inc., Bound Brook, New Jersey
Crag Agricultural Chemicals Division, Carbide and Carbon Chemicals Co., New York, New York
Deere and Company, Product Research Dept., Moline, Illinois
Diamond Alkali Company, Cleveland, Ohio
The Dow Chemical Company, Midland, Michigan
E. I. duPont deNemours & Company, Inc., Grasselli Chemicals Dept., Wilmington, Delaware
G.L.F. Soil Building Service, Ithaca, New York
Geigy Agricultural Chemicals, Div. of Geigy Chemical Corp., Yonkers, New York
Hercules Powder Company, Wilmington, Delaware
International Harvester Company, Chicago, Illinois
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Company, Chicago, Illinois
Olin Mathieson Chemical Corp., Baltimore, Maryland
O. M. Scott and Sons Company, Marysville, Ohio
Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
United States Borax and Chemical Corp., Los Angeles, California

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
April, May, and June, 1956

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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Field Crops Research Branch

The bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography, the Field Crops Research Branch, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

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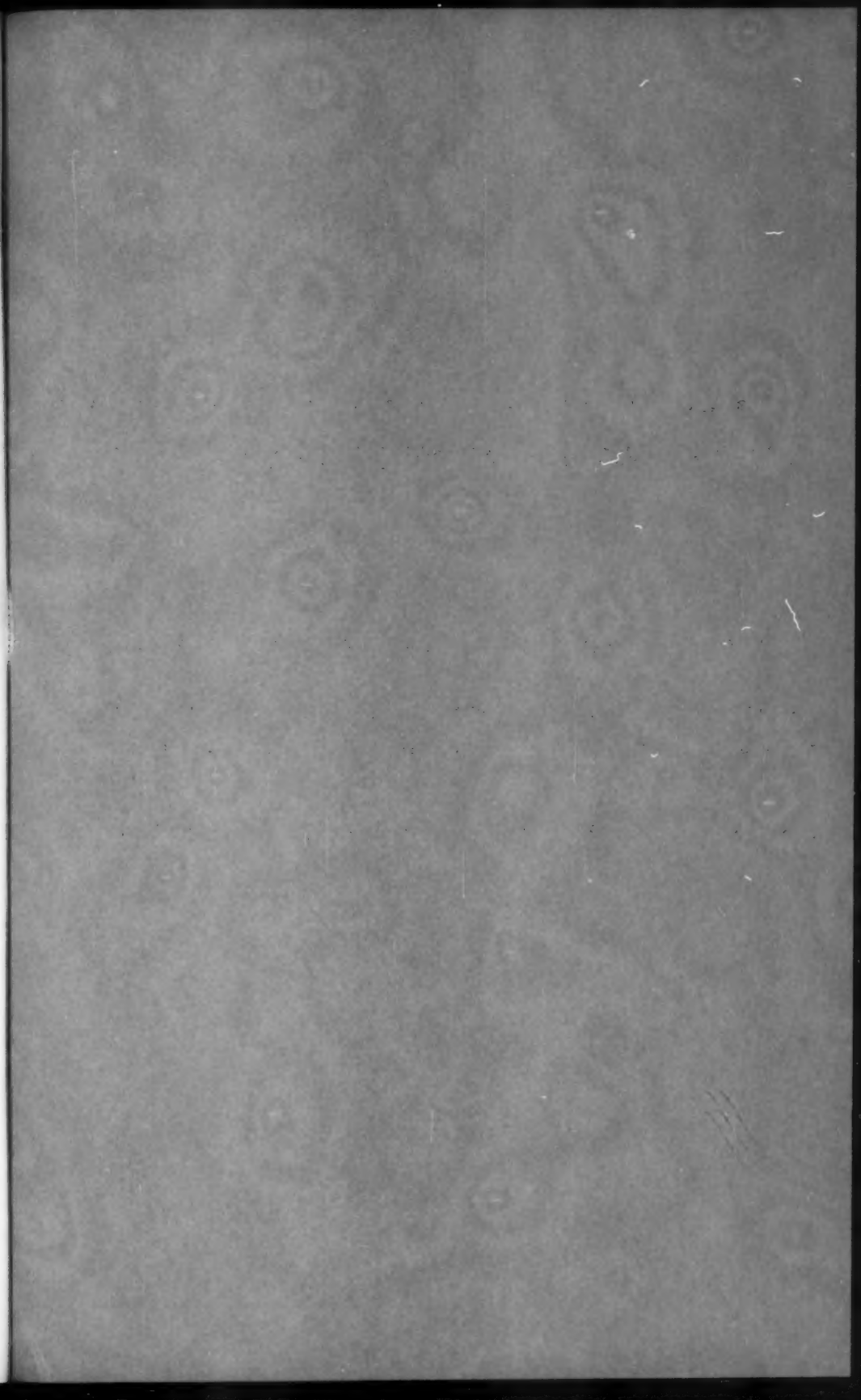
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